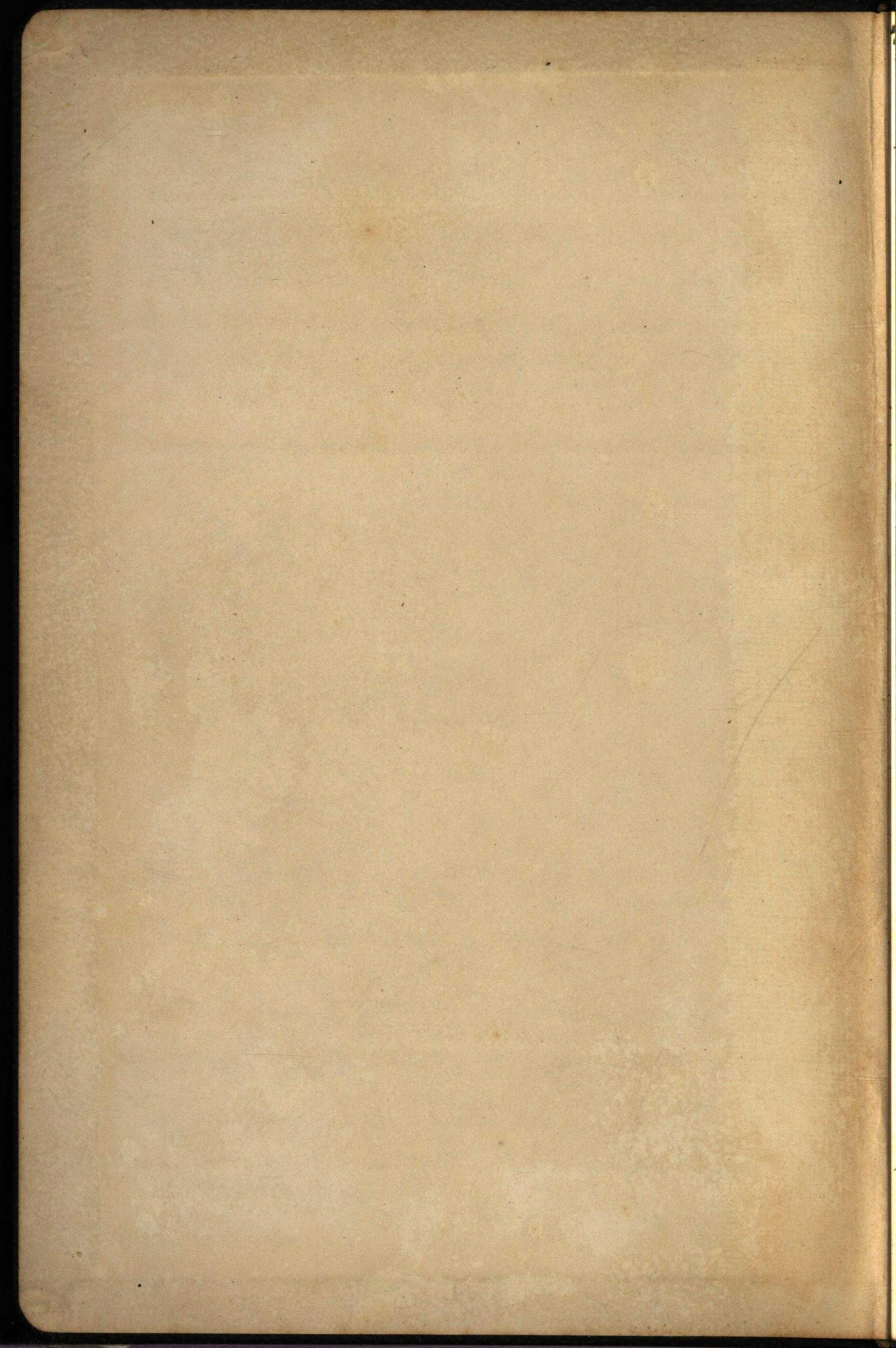


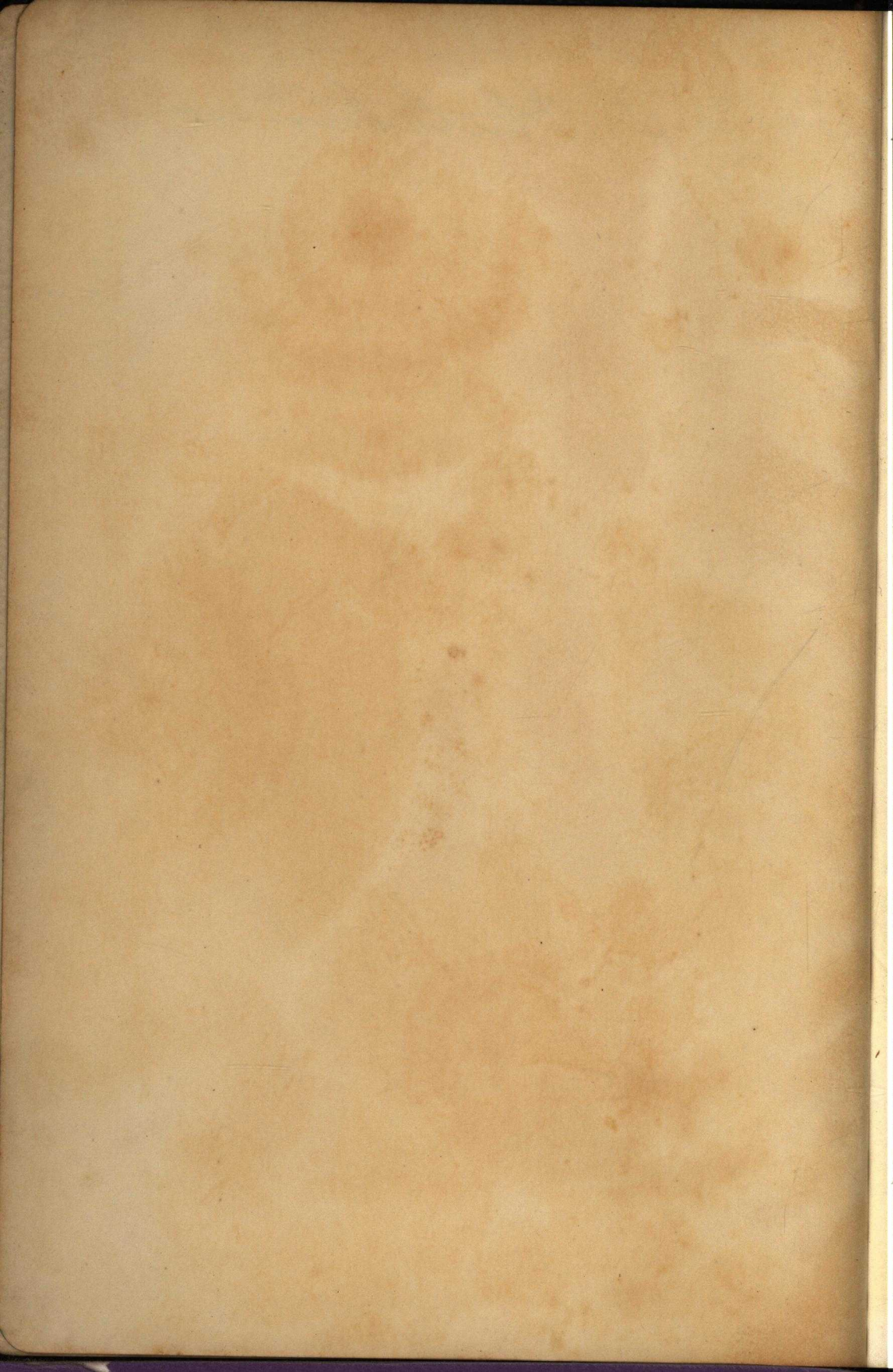
BETHLEHEM ALLOY STEELS

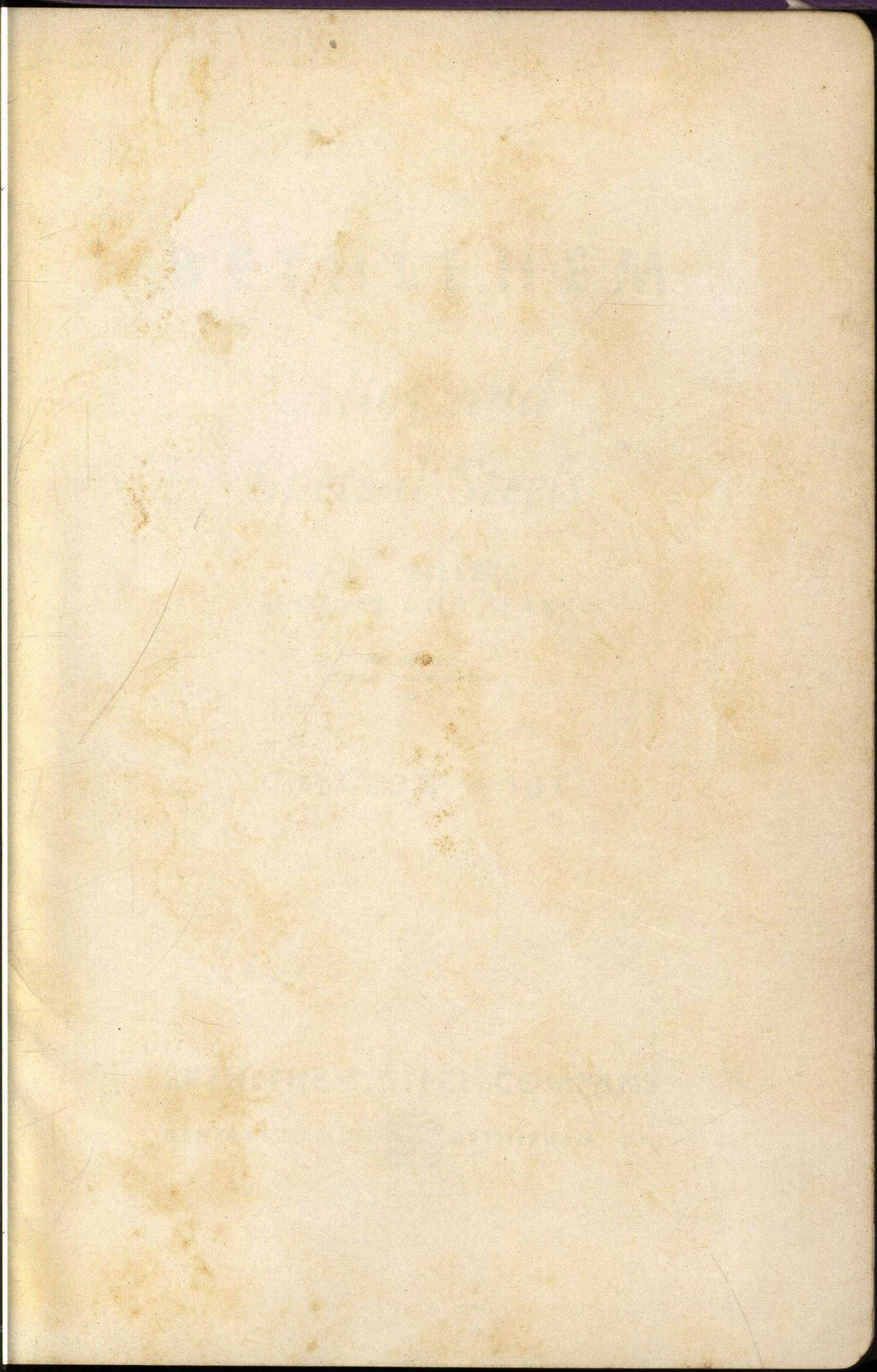


BETHLEHEM STEEL COMPANY
BETHLEHEM PENNSYLVANIA



520-
C. C. Hutchinson





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Bethlehem Steel Company
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BETHLEHEM

*Alloy and
Special Steels*

**BARS, BILLETS,
BLOOMS AND SLABS**

CATALOG — 107

BETHLEHEM STEEL COMPANY

GENERAL OFFICES



BETHLEHEM, PA.



Night view of Lehigh Plant, Bethlehem Steel Company, Bethlehem, Pa.

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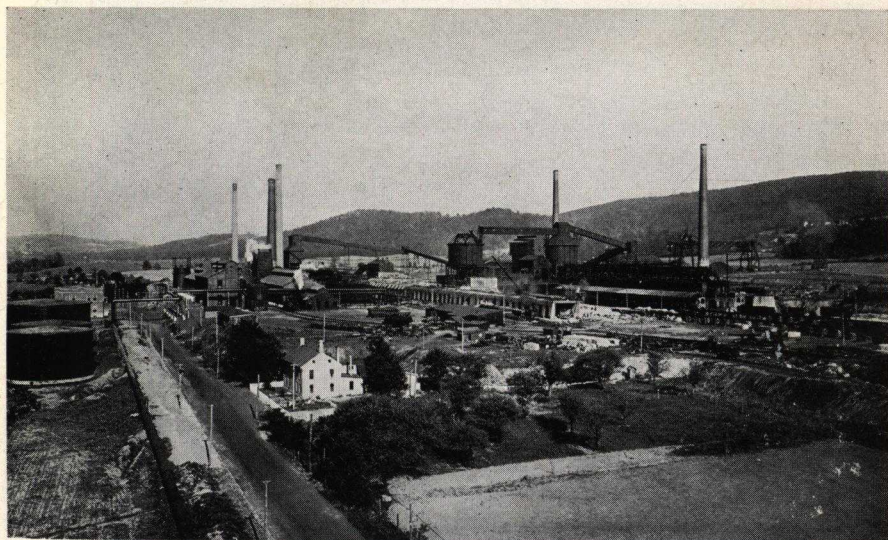
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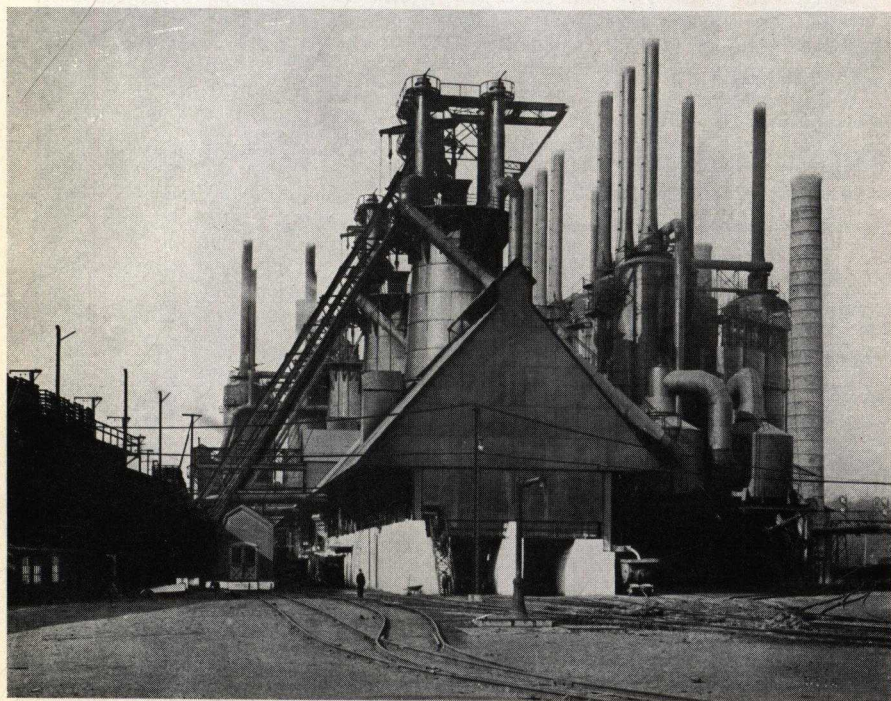


Metallographic examination

ALLOY STEELS

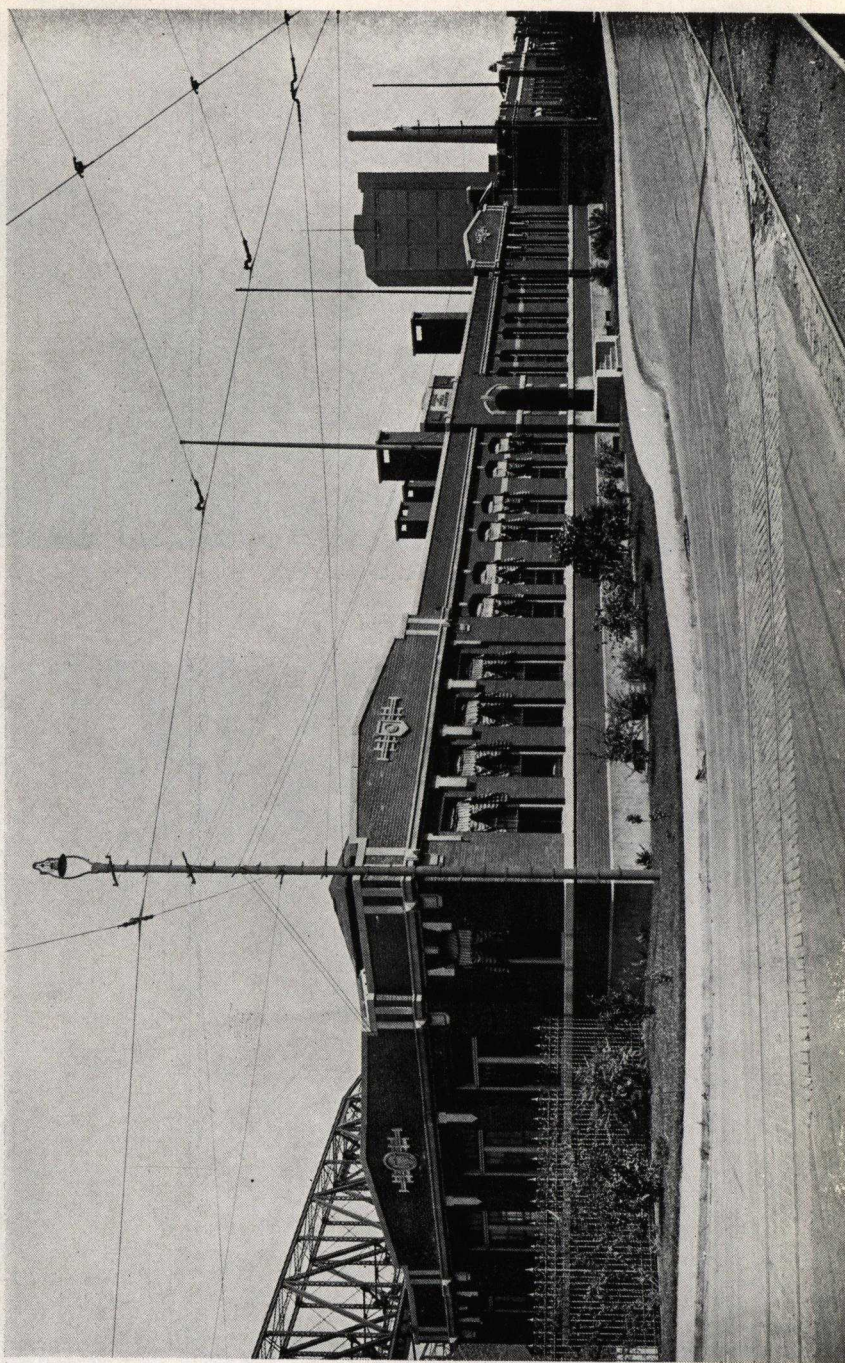


The coke plant, Bethlehem, Pa.



One of the blast furnaces, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY



The main chemical and physical laboratory at Bethlehem

PREFACE

BETHLEHEM STEEL COMPANY, the pioneer producer of alloy steel in the United States, lays claim to this distinction through the work carried out by its immediate predecessor, the Bethlehem Iron Company.

The late eighties and early nineties saw the development of alloy steel mainly as applied to forgings. Some of these were of very large sizes, as for example, the shaft for the original Ferris Wheel at the World's Columbian Exposition, Chicago, 1893; a large crankshaft for the Boston Elevated Railway; and the moving parts for the immense Calumet and Hecla pump.

Another interesting early use of alloy steel was in the large heat-treated nickel-steel field rings which, in 1893, made possible the completion of Niagara Falls Power Company plant without serious modifications of design affecting the capacity of units.

The failures of large stern wheel boat shafts on the Mississippi River caused great loss both in life and property. The problem was successfully solved when Bethlehem replaced the wrought iron shafts and the German crucible steel shafts with hollow-forged heat-treated nickel-steel shafts. One of these early shafts gave more than thirty years continuous service.

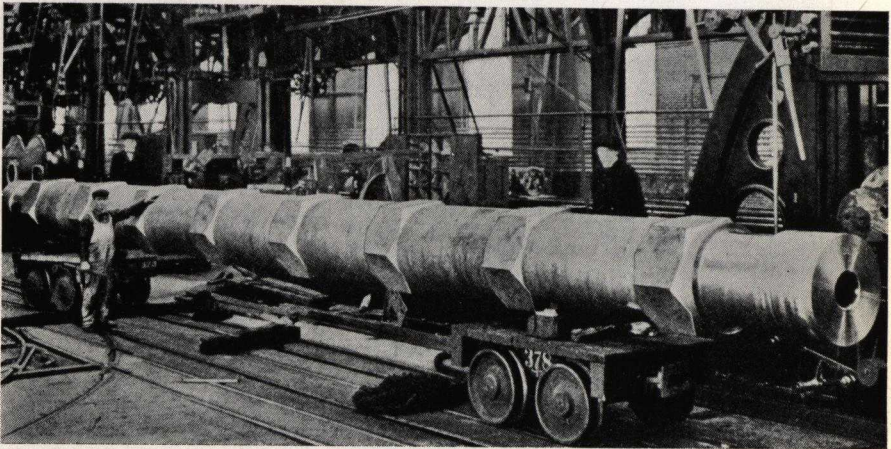
Paralleling the adoption of alloy steel to commercial work was the interesting use of alloy steel for shafting in fighting ships, for machine parts, and ordnance. Bethlehem furnished nickel-steel forgings for the first 16-inch gun in the United States, which was assembled at Watertown Arsenal in 1898.

In a few years alloy steel armor plate made obsolete all other protective armament. In June, 1887, Bethlehem concluded the first American contract for modern armor plate, consisting of 7,155 tons of carbon steel for two battleships and four monitors. Since this required a new forge plant, production on this order was started in 1890. During this interval, because of the excellent qualities developed in experimental nickel-steel plates, the contract was changed from carbon to nickel steel.

BETHLEHEM STEEL COMPANY

In 1891, Mr. H. A. Harvey developed the face-hardened armor plate in the Bethlehem plant, which was the next step in improving the defensive protection of a fighting ship. Immediately following this, Bethlehem developed the reforging practice in connection with Harveyized plates, resulting in the most satisfactory armor plate in the world up to that time.

Another important feature in the development of alloy steels took place in 1900 when the late Frederick W. Taylor and Maunsell White, after a number of years of research work in the Bethlehem plant, announced the development of the first high speed cutting steel. As a result of this notable achievement, it was possible to bring into reality what we now know as modern machine shop practice. The machine tool industry was revolutionized since heavier machines with more power were required in order to realize the full efficiency of this new product which made possible increased production with decreased operating costs.



First hollow-forged nickel-steel shaft for a stern wheel steamer. Length, 47 feet; outside diameter, 31 inches; inside diameter, 21 inches; closed down to 10 inches at the ends. Shipped weight, 80,220 lbs. Forged, machined and heat treated at Bethlehem Plant

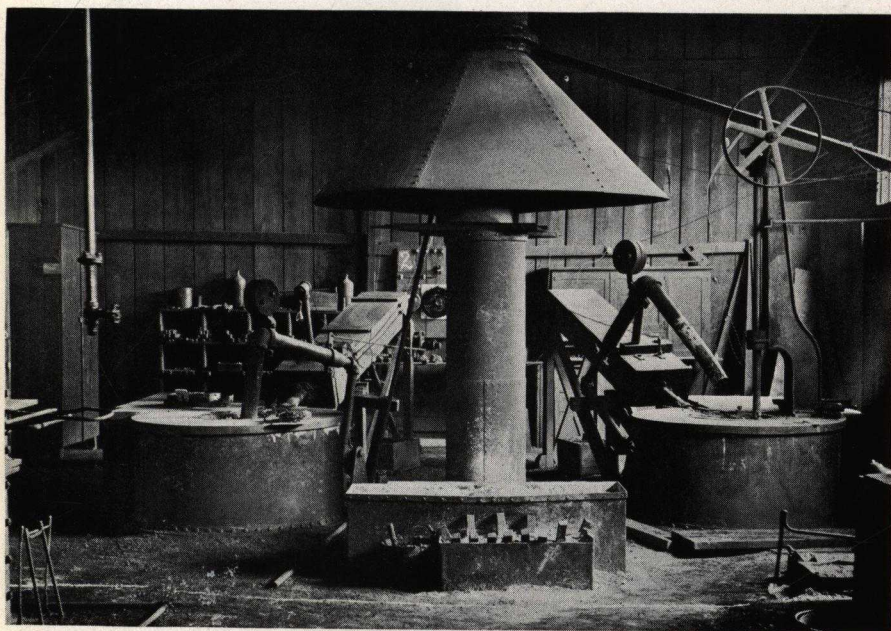
Bethlehem pioneered in the development of the corrugated, large-end-up ingot with a sink-head that is now used, with slight modifications, by practically all producers of high grade steels. Blueprints No. 11151 dated February 27, 1900, No. 11736 dated

ALLOY STEELS

June 11, 1900, and No. 11743 dated June 28, 1900, cover the drawings of the first ingot molds of this type to be put into service at the Bethlehem plant. This development was a most important factor in the successful production of high grade steel, especially alloy steel.

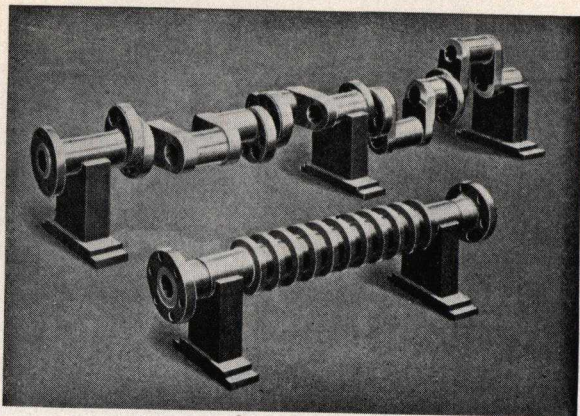
Bethlehem Steel Company continues its practical research work, thus maintaining a foremost position in the production of alloy and special purpose steels. In development work each man is assigned a specific problem and regardless of industrial conditions, the project is continued to completion. Bethlehem is continually increasing the scope of its research facilities in order to keep abreast of the rapid developments in the application of steel to the projects of science and industry.

The importance of alloy steel in industry is indicated by its increasing use. The curve which represents the percentage of all steels made that are of the alloy type is constantly rising. In



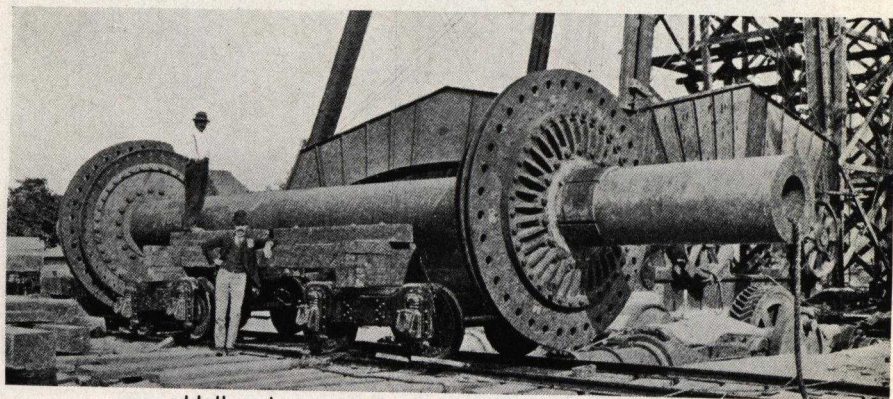
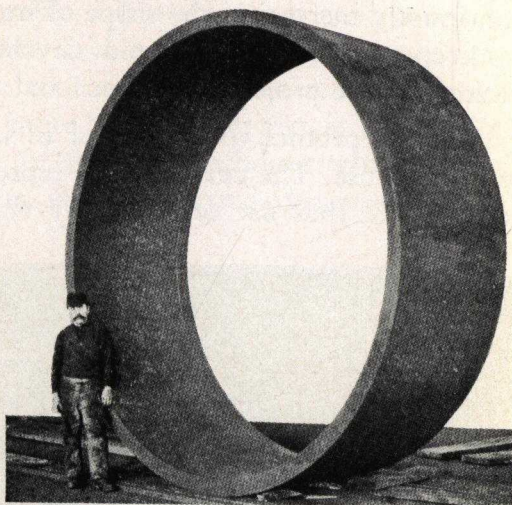
Taylor-White experimental laboratory, Bethlehem, Pa., about 1899

BETHLEHEM STEEL COMPANY



Crank and thrust shafts for the U. S. torpedo boat "Shubrick," launched Oct. 31, 1899, made of heat-treated nickel steel; $6\frac{3}{4}$ inches outside diameter; 4 inches axial hole, each forged in one piece; crankshaft turned on 13 centers, weight of crankshaft, 1650 lbs.; weight of thrust shaft, 1800 lbs.

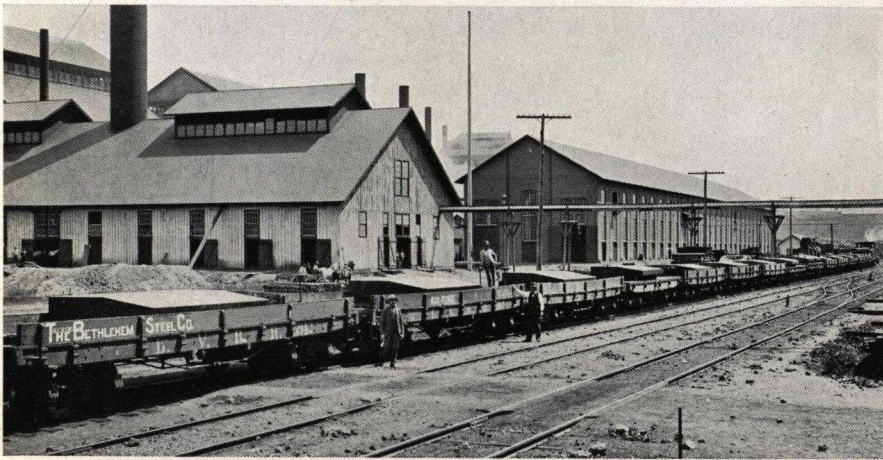
One of a large number of nickel-steel field rings forged without a weld at the Bethlehem Plant in 1893, for 5000 h.p. generators at the Niagara Falls power plant. Diameter, 11 feet, $7\frac{3}{8}$ inches; width, 4 feet, $2\frac{3}{4}$ inches; weight, 28,840 pounds



Hollow, heat-treated nickel-steel shaft for Ferris wheel
World Columbian Exposition, Chicago, 1893

1909, 181,980 tons of alloy steel were made, representing 0.75 per cent of all steel made in the United States that year. By 1934 the percentage had increased approximately ten fold.

In a presentation of this nature it is impossible to furnish complete and detailed information on all of the subjects discussed. The Bethlehem practice is to consider problems of customers as part of the usual procedure and to offer the fullest cooperation to customers and other interested parties. A corps of engineers is maintained for the purpose of discussing details pertaining to design, grade or quality of steel, chemistry, machinability, or other problems that arise in steel products and their application and processing. A cordial invitation is extended to the users of this publication to avail themselves of this service and to visit the Bethlehem plants to become acquainted with the operating personnel who are responsible for the quality of the product.



An early shipment of nickel-steel armor plate from the Bethlehem plant

BETHLEHEM STEEL COMPANY



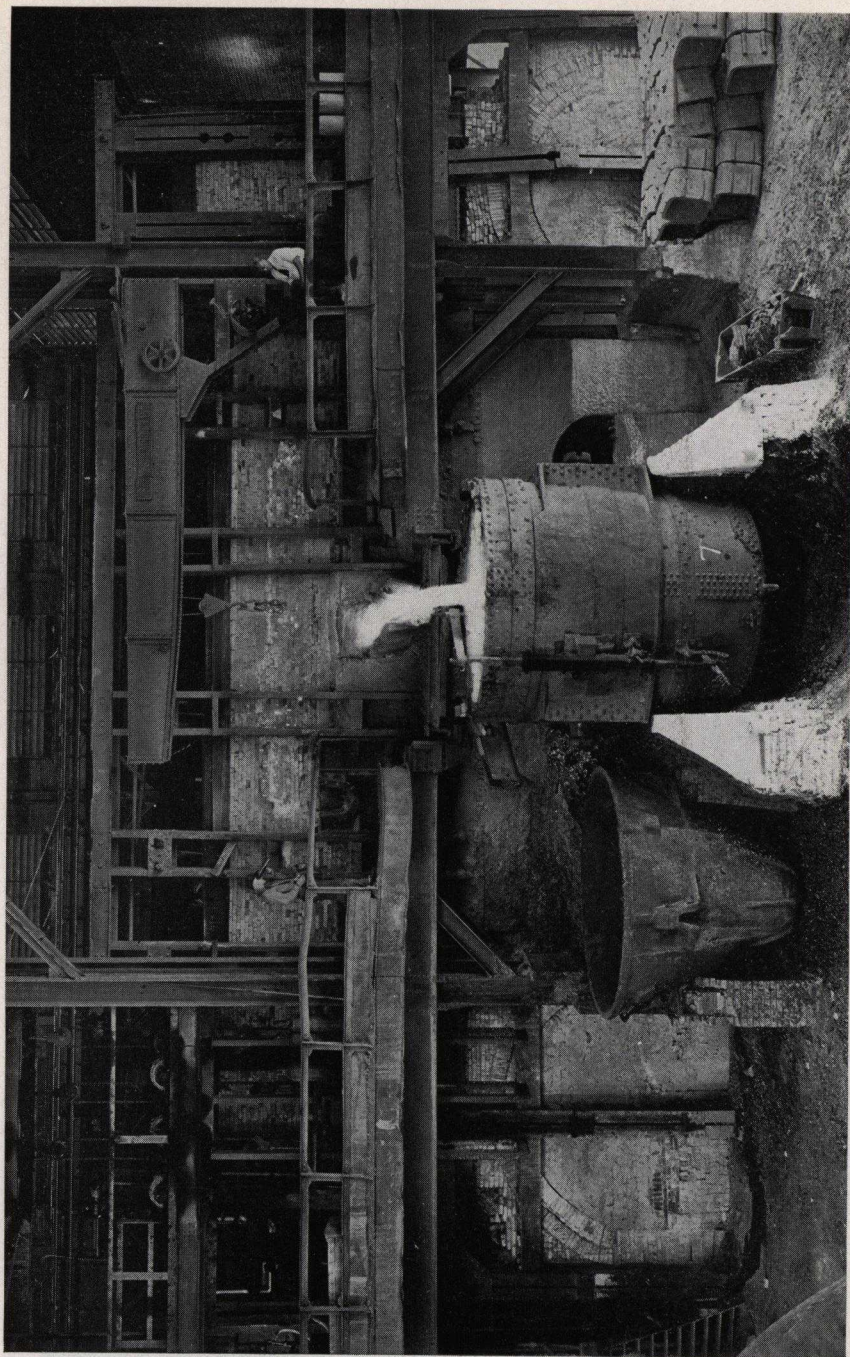
Replica of 125-ton hammer at the World's Columbian Exposition, 1893. The original hammer was in service in the Bethlehem Plant from 1891 to 1894 and was taken out of service because of concussion effects on nearby shops and buildings. Piston rod was heat-treated nickel steel

ALLOY STEELS



Charging floor at front of open hearth furnaces

BETHLEHEM STEEL COMPANY



Tapping open hearth furnace at the back. Note metallurgical observer taking temperature with optical pyrometer in order to issue instructions on holding interval and rate of teeming

BETHLEHEM'S ALLOY STEEL PRODUCTION FACILITIES

BETHLEHEM STEEL COMPANY has ample melting facilities, exclusively devoted to the production of alloy and special purpose steels, to supply steel for the specialty rolling mills, forging plants and foundries. The open hearth department is equipped with both acid and basic lined furnaces and the electric furnace department is provided with both arc and induction melting furnaces.

In making steel, the scrap requirements of the open hearth are considerably greater than the scrap production of the open hearth and the departments processing its product. It is, therefore, necessary to have other sources. In the production of alloy steel, it is very important that the character of the scrap be suitable, not only from a chemical, but also from a physical standpoint. A number of years ago, Bethlehem Steel Company created a scrap-preparing department for this purpose. All purchased and miscellaneous scrap is carefully sorted and the proper grade of selected scrap is allocated to the department for its use.

Bethlehem produces alloy steels in many different forms including large and small forgings, rolled bars, blooms, billets, and shapes; tool steels and stainless steels of the different types, castings, plates and various other products. In this publication the comments are confined primarily to rolled products as covered by the terms alloy and special purpose steel bars, billets and blooms. With this in view it will be well at this point to discuss briefly the mills and their auxiliary equipment. Information about other alloy steel products will be gladly furnished upon request.

The specialty rolling mills are not of the high-speed continuous type used in producing the common grades of steel, but were designed for the rolling of quality steels and readily lend them-

selves to the heat control necessary for alloy and special requirement steels. Coiling equipment is available at the small mills. In addition to the usual cooling beds, pits and ash beds are available for retarded cooling.

The facilities for surface preparation of billets and bars comprise adequate pickling capacity, extensive chipping beds, and batteries of billet grinders so arranged and served as to insure the highest quality of workmanship.

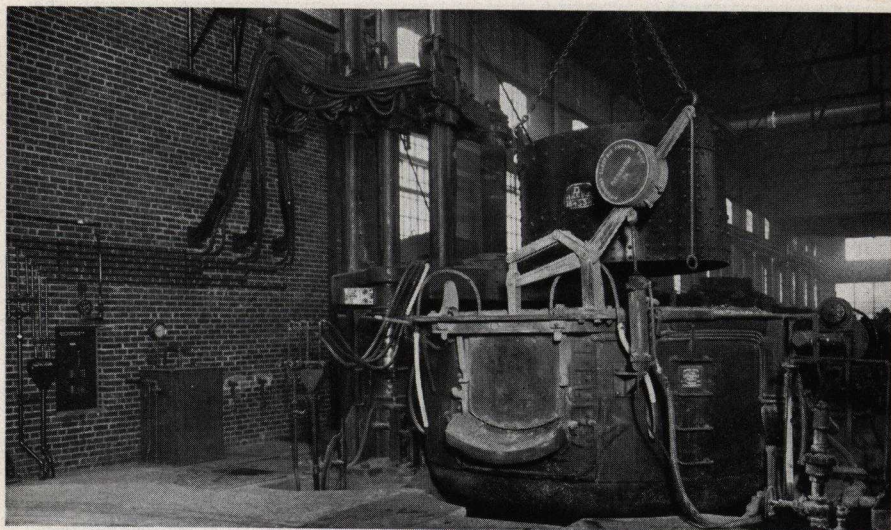
For expeditious service, two metallurgical laboratories are conveniently located in the mills, with ample facilities to take care of all control work and hot acid etch testing. Complete metallographic and heat-treatment service for the inspection, metallurgical and applied research activities of the alloy mills are also available in these branch laboratories.

One bay is set aside for inspection of the finished product, in which every facility is provided, including a modern shear for testing the cold shearing qualities of both bars and billets. This section is also provided with equipment for spark testing, spot testing and special inspection which is supplementary to the regular and routine inspection facilities at each individual mill.

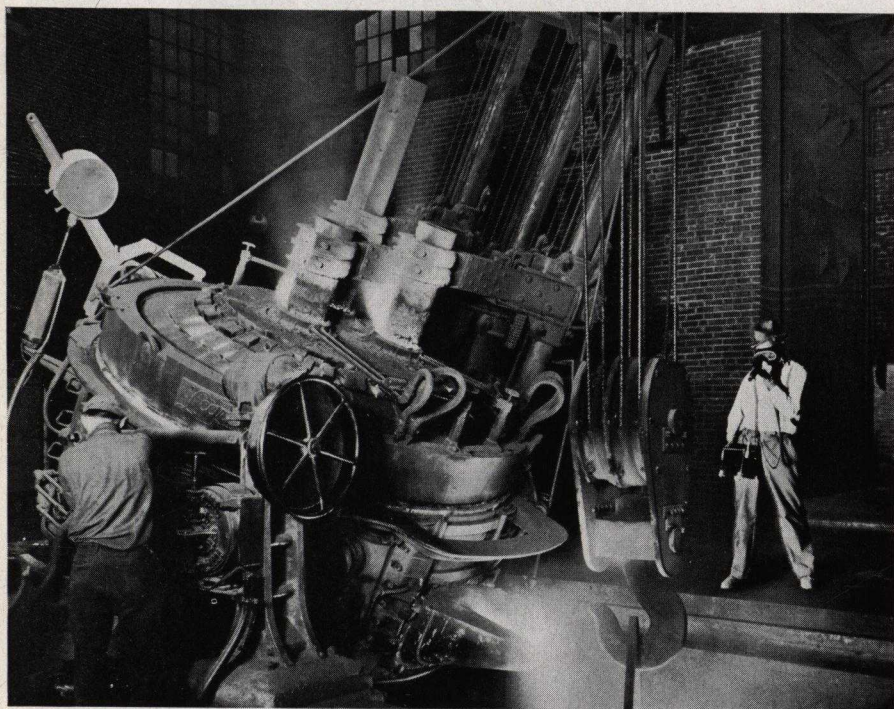
There is a complete electric furnace heat-treating plant operating under pyrometric control. This unit consists of pre-heating and heating furnaces for quenching or normalizing material; two pit-type furnaces for annealing or drawing; and two car-type furnaces for annealing, normalizing or drawing. The shop is thoroughly equipped for testing and straightening the products.

The cold-drawing shop, limited exclusively to alloy steels, is equipped with benches for drawing bars and with bull blocks for coils. Pickling and cleaning facilities are provided and the necessary straightening equipment for rounds, hexagons, octagons, squares, flats, as well as many special shapes. To provide for extreme refinement in surface and tolerance, the shop has been equipped with a battery of centerless grinders.

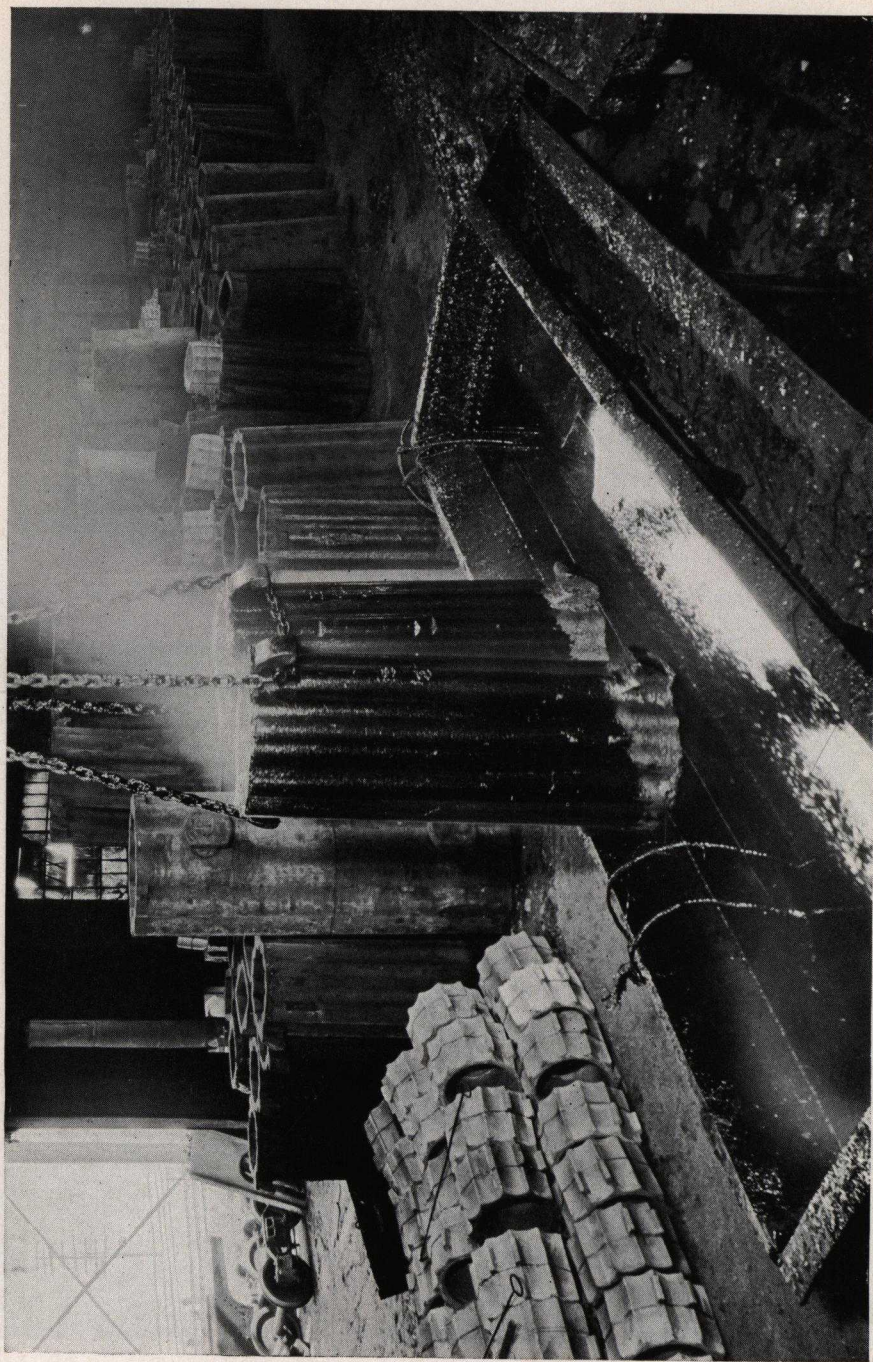
ALLOY STEELS



Charging an electric furnace



Tapping an electric furnace



Preparing ingot mold surfaces to insure a good skin on the ingot when poured

QUALITY CONTROL

IN THE production of alloy and special steels, the control of quality necessitates an ample supply of good raw materials, adequate manufacturing and laboratory equipment, trained and experienced operating personnel, close independent metallurgical supervision, and a plant laid out and managed so that it can be controlled and operated as an integrated unit for the product involved.

Proper organization is most essential in the control of quality. In the Bethlehem organization one man is directly responsible for all manufacturing operations on each particular product, and another man directly responsible for the metallurgical control. Each functions independently of the other but both report to the chief executive of the plant.

The Bethlehem metallurgical control covers a very broad field involving the selection and checking of raw materials, material in process and the final product. It also includes the managing of the chemical, physical, metallographic and other laboratories. Every kind of inspection of the product falls within this jurisdiction. Naturally, all experimental and development projects are supervised by this division.

Included in the metallurgical control system is a group of trained men who follow all operations from the introduction of the ore into the blast furnace to the completion of the last metallurgical operation. This corps of men, known as "observers" do not function as mechanical or detail inspectors. Bethlehem has laid down fixed standards and set up practices to maintain on each of the operations for each grade of steel. The observers' duties are to see that the standards are rigidly adhered to, and in certain cases they, rather than the operating superintendent, are the authority to issue instructions on the manner of processing. This group of men is held responsible for the quality of the product and they have the authority to stop the operation and

reject the steel at any time when the standard is not being maintained, even though it may be due to unusual or abnormal combinations of conditions.

There are many cases where close metallurgical contact with customers makes all the difference between success or failure in furnishing a product which will process satisfactorily and give good service. This contact is made through a group of trained men whose duties are to provide metallurgical services to customers and to furnish the manufacturing division with pertinent information on details of operations which will improve the service to customers. Customers' metallurgical problems are considered by Bethlehem as a mutual responsibility and their solution a dual achievement.

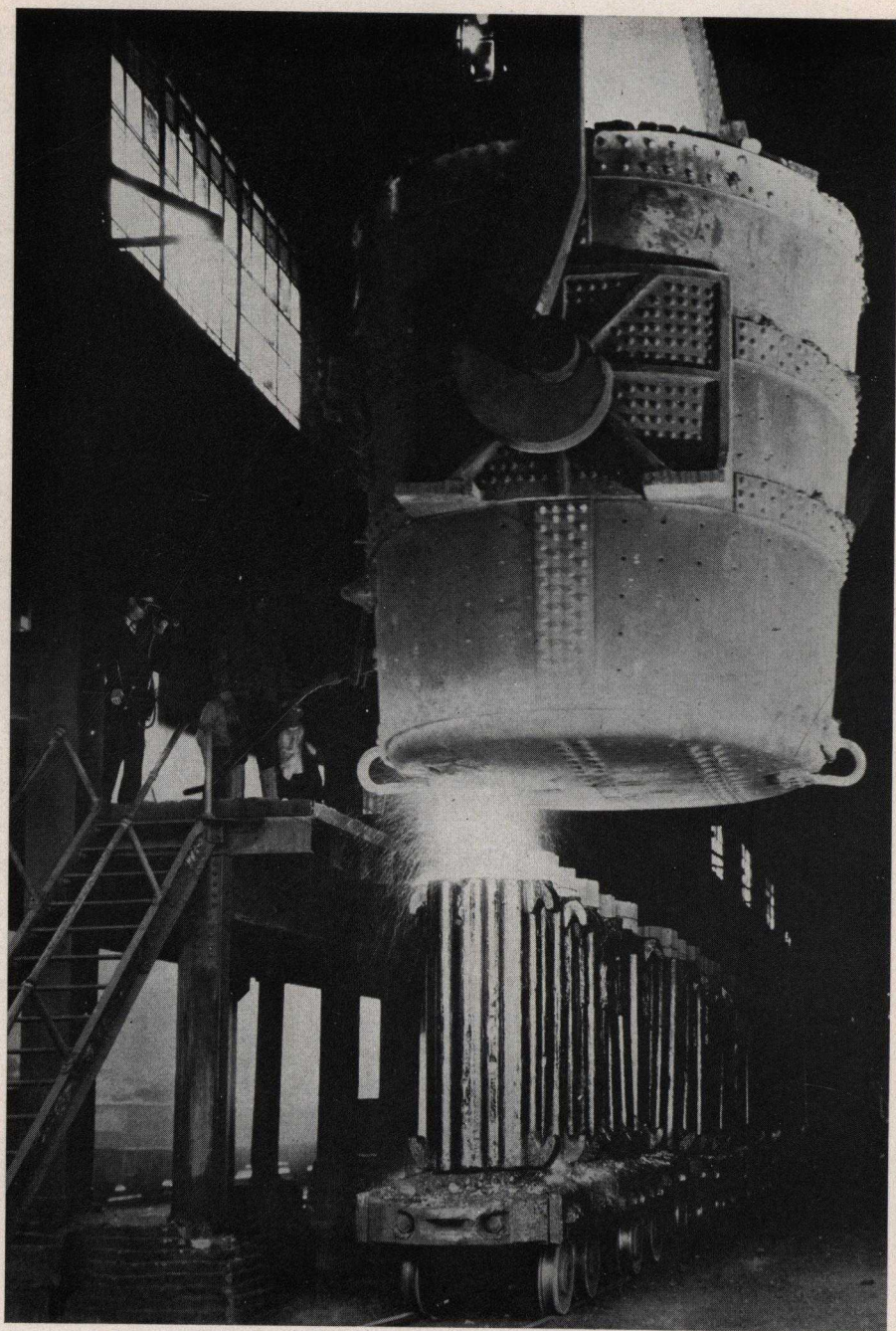
The very important function of issuing complete metallurgical instructions to the operating personnel is given the closest attention. This means covering not only what is printed in the specifications but also that which, by experience and continuous interchange of information with customers, is known to be necessary to furnish a product that will be most satisfactory. The final authority and responsibility for the approval of steel before shipment is included under metallurgical control.

The layout of the Bethlehem mills is excellently adapted to the organization plan. All operating units are grouped so that no long hauls or delays are encountered which would interfere with the strict instructions regarding the thermal handling or control of the steel.



Siphon cleaning ingot molds before pouring

BETHLEHEM STEEL COMPANY



Pouring corrugated hot-top ingots. Note observer checking temperatures

PART 1

GRADES OF STEEL

S. A. E. STEELS

TYPES OF ALLOY AND SPECIAL
PURPOSE CARBON STEELS

SPECIAL CARBON STEELS

MEDIUM MANGANESE STEELS

NICKEL STEELS

NICKEL-CHROMIUM STEELS

MOLYBDENUM ALLOY STEELS

CHROMIUM STEELS

VANADIUM ALLOY STEELS

SILICO-MANGANESE STEELS



Stripping alloy steel ingots from molds



Charging an ingot of alloy steel into a soaking pit

GRADES OF STEEL

THE S. A. E. series of analyses is generally recognized as the basis for numerical representation and division of ranges of chemical analysis in the United States. Many users of alloy and special-purpose steels have their own chemical ranges, but in general, where a number of different ranges are involved, the S. A. E. grading is used as the basis.

Bethlehem, in its series of standard analyses, likewise follows the S. A. E. system with variations to denote special ranges in the elements where they deviate from the S. A. E. standards. Bethlehem is prepared to furnish grades of steels of the S. A. E. series. In addition to this the Bethlehem series includes many intermediate grades not shown by S. A. E. but which have been found to be in popular demand or are used for special purposes.



Blooming mill. Observer recording temperature

S. A. E. STEELS

Revised 1935

Carbon Steels

S.A.E. No.	C.	Mn.	P. (max.)	S. (max.)
1010	0.05-0.15	0.30-0.60	0.045	0.055
1015	0.10-0.20	0.30-0.60	0.045	0.055
X1015	0.10-0.20	0.70-1.00	0.045	0.055
1020	0.15-0.25	0.30-0.60	0.045	0.055
X1020	0.15-0.25	0.70-1.00	0.045	0.055
1025	0.20-0.30	0.30-0.60	0.045	0.055
X1025	0.20-0.30	0.70-1.00	0.045	0.055
1030	0.25-0.35	0.60-0.90	0.045	0.055
1035	0.30-0.40	0.60-0.90	0.045	0.055
1040	0.35-0.45	0.60-0.90	0.045	0.055
X1040	0.35-0.45	0.40-0.70	0.045	0.055
1045	0.40-0.50	0.60-0.90	0.045	0.055
X1045	0.40-0.50	0.40-0.70	0.045	0.055
1050	0.45-0.55	0.60-0.90	0.045	0.055
X1050	0.45-0.55	0.40-0.70	0.045	0.055
1055	0.50-0.60	0.60-0.90	0.040	0.055
X1055	0.50-0.60	0.90-1.20	0.040	0.055
1060	0.55-0.70	0.60-0.90	0.040	0.055
1065	0.60-0.75	0.60-0.90	0.040	0.055
X1065	0.60-0.75	0.90-1.20	0.040	0.055
1070	0.65-0.80	0.60-0.90	0.040	0.055
1075	0.70-0.85	0.60-0.90	0.040	0.055
1080	0.75-0.90	0.60-0.90	0.040	0.055
1085	0.80-0.95	0.60-0.90	0.040	0.055
1090	0.85-1.00	0.60-0.90	0.040	0.055
1095	0.90-1.05	0.25-0.50	0.040	0.055

Free-Cutting Steels

S.A.E. No.	C.	Mn.	P.	S.
1112	0.08-0.16	0.60-0.90	0.09-0.13	0.10-0.20
X1112	0.08-0.16	0.60-0.90	0.09-0.13	0.20-0.30
1115	0.10-0.20	0.70-1.00	0.045 max.	0.075-0.15
1120	0.15-0.25	0.60-0.90	0.045 max.	0.075-0.15
X1314	0.10-0.20	1.00-1.30	0.045 max.	0.075-0.15
X1315	0.10-0.20	1.30-1.60	0.045 max.	0.075-0.15
X1330	0.25-0.35	1.35-1.65	0.045 max.	0.075-0.15
X1335	0.30-0.40	1.35-1.65	0.045 max.	0.075-0.15
X1340	0.35-0.45	1.35-1.65	0.045 max.	0.075-0.15

S. A. E. STEELS

Revised 1935

Manganese Steels¹

S.A.E. No.	C.	Mn.	P.(max.)	S.(max.)
T1330	0.25-0.35	1.60-1.90	0.040	0.050
T1335	0.30-0.40	1.60-1.90	0.040	0.050
T1340	0.35-0.45	1.60-1.90	0.040	0.050
T1345	0.40-0.50	1.60-1.90	0.040	0.050
T1350	0.45-0.55	1.60-1.90	0.040	0.050

Nickel Steels¹

S.A.E. No.	C.	Mn.	P.(max.)	S.(max.)	Ni.
2015	0.10-0.20	0.30-0.60	0.040	0.050	0.40-0.60
2115	0.10-0.20	0.30-0.60	0.040	0.050	1.25-1.75
2315	0.10-0.20	0.30-0.60	0.040	0.050	3.25-3.75
2320	0.15-0.25	0.30-0.60	0.040	0.050	3.25-3.75
2330	0.25-0.35	0.50-0.80	0.040	0.050	3.25-3.75
2335	0.30-0.40	0.50-0.80	0.040	0.050	3.25-3.75
2340	0.35-0.45	0.60-0.90	0.040	0.050	3.25-3.75
2345	0.40-0.50	0.60-0.90	0.040	0.050	3.25-3.75
2350	0.45-0.55	0.60-0.90	0.040	0.050	3.25-3.75
2515	0.10-0.20	0.30-0.60	0.040	0.050	4.75-5.25

Nickel-Chromium Steels¹

S.A.E. No.	C.	Mn.	P.(max.)	S.(max.)	Ni.	Cr.
3115	0.10-0.20	0.30-0.60	0.040	0.050	1.00-1.50	0.45-0.75
3120	0.15-0.25	0.30-0.60	0.040	0.050	1.00-1.50	0.45-0.75
3125	0.20-0.30	0.50-0.80	0.040	0.050	1.00-1.50	0.45-0.75
3130	0.25-0.35	0.50-0.80	0.040	0.050	1.00-1.50	0.45-0.75
3135	0.30-0.40	0.50-0.80	0.040	0.050	1.00-1.50	0.45-0.75
3140	0.35-0.45	0.60-0.90	0.040	0.050	1.00-1.50	0.45-0.75
X3140	0.35-0.45	0.60-0.90	0.040	0.050	1.00-1.50	0.60-0.90
3145	0.40-0.50	0.60-0.90	0.040	0.050	1.00-1.50	0.45-0.75
3150	0.45-0.55	0.60-0.90	0.040	0.050	1.00-1.50	0.45-0.75
3215	0.10-0.20	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
3220	0.15-0.25	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
3230	0.25-0.35	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
3240	0.35-0.45	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
3245	0.40-0.50	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
3250	0.45-0.55	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
3312	0.17 max.	0.30-0.60	0.040	0.050	3.25-3.75	1.25-1.75
3325	0.20-0.30	0.30-0.60	0.040	0.050	3.25-3.75	1.25-1.75
3335	0.30-0.40	0.30-0.60	0.040	0.050	3.25-3.75	1.25-1.75
3340	0.35-0.45	0.30-0.60	0.040	0.050	3.25-3.75	1.25-1.75
3415	0.10-0.20	0.30-0.60	0.040	0.050	2.75-3.25	0.60-0.95
3435	0.30-0.40	0.30-0.60	0.040	0.050	2.75-3.25	0.60-0.95
3450	0.45-0.55	0.30-0.60	0.040	0.050	2.75-3.25	0.60-0.95

¹ Silicon range of all S. A. E. basic open hearth alloy steels shall be 0.15 to 0.30 per cent. For electric and acid open hearth alloy steels the silicon content shall be 0.15 per cent min.

S. A. E. STEELS

Revised 1935

Molybdenum Steels¹

S.A.E. No.	C.	Mn.	P.(max.)	S.(max.)	Ni.	Cr.	Mo.
4130	0.25-0.35	0.50-0.80	0.040	0.050	.....	0.50-0.80	0.15-0.25
X4130	0.25-0.35	0.40-0.60	0.040	0.050	.....	0.80-1.10	0.15-0.25
4135	0.30-0.40	0.60-0.90	0.040	0.050	.....	0.80-1.10	0.15-0.25
4140	0.35-0.45	0.60-0.90	0.040	0.050	.....	0.80-1.10	0.15-0.25
4150	0.45-0.55	0.60-0.90	0.040	0.050	.....	0.80-1.10	0.15-0.25
4340	0.35-0.45	0.50-0.80	0.040	0.050	1.50-2.00	0.50-0.80	0.30-0.40
4345	0.40-0.50	0.50-0.80	0.040	0.050	1.50-2.00	0.60-0.90	0.15-0.25
4615	0.10-0.20	0.40-0.70	0.040	0.050	1.65-2.00	.....	0.20-0.30
4620	0.15-0.25	0.40-0.70	0.040	0.050	1.65-2.00	.....	0.20-0.30
4640	0.35-0.45	0.50-0.80	0.040	0.050	1.65-2.00	.....	0.20-0.30
4815	0.10-0.20	0.40-0.60	0.040	0.050	3.25-3.75	.....	0.20-0.30
4820	0.15-0.25	0.40-0.60	0.040	0.050	3.25-3.75	.....	0.20-0.30

Chromium Steels¹

S.A.E. No.	C.	Mn.	P.(max.)	S.(max.)	Cr.
5120	0.15-0.25	0.30-0.60	0.040	0.050	0.60-0.90
5140	0.35-0.45	0.60-0.90	0.040	0.050	0.80-1.10
5150	0.45-0.55	0.60-0.90	0.040	0.050	0.80-1.10
52100	0.95-1.10	0.20-0.50	0.030	0.035	1.20-1.50

Chromium-Vanadium Steels¹

S.A.E. No.	C.	Mn.	P.(max.)	S.(max.)	Cr.	Vanadium	
						min.	desired
6115	0.10-0.20	0.30-0.60	0.040	0.050	0.80-1.10	0.15	0.18
6120	0.15-0.25	0.30-0.60	0.040	0.050	0.80-1.10	0.15	0.18
6125	0.20-0.30	0.60-0.90	0.040	0.050	0.80-1.10	0.15	0.18
6130	0.25-0.35	0.60-0.90	0.040	0.050	0.80-1.10	0.15	0.18
6135	0.30-0.40	0.60-0.90	0.040	0.050	0.80-1.10	0.15	0.18
6140	0.35-0.45	0.60-0.90	0.040	0.050	0.80-1.10	0.15	0.18
6145	0.40-0.50	0.60-0.90	0.040	0.050	0.80-1.10	0.15	0.18
6150	0.45-0.55	0.60-0.90	0.040	0.050	0.80-1.10	0.15	0.18
6195	0.90-1.05	0.20-0.45	0.030	0.035	0.80-1.10	0.15	0.18

Tungsten Steels¹

S.A.E. No.	C.	Mn.(max.)	P.(max.)	S.(max.)	Cr.	W.
71360	0.50-0.70	0.30	0.035	0.040	3.00-4.00	12.00-15.00
71660	0.50-0.70	0.30	0.035	0.040	3.00-4.00	15.00-18.00
7260	0.50-0.70	0.30	0.035	0.040	0.50-1.00	1.50- 2.00

¹ Silicon range of all S. A. E. basic open hearth alloy steels shall be 0.15 to 0.30 per cent. For electric and acid open hearth alloy steels the silicon content shall be 0.15 per cent min.

S. A. E. STEELS

Revised 1935

Silico-Manganese Steels

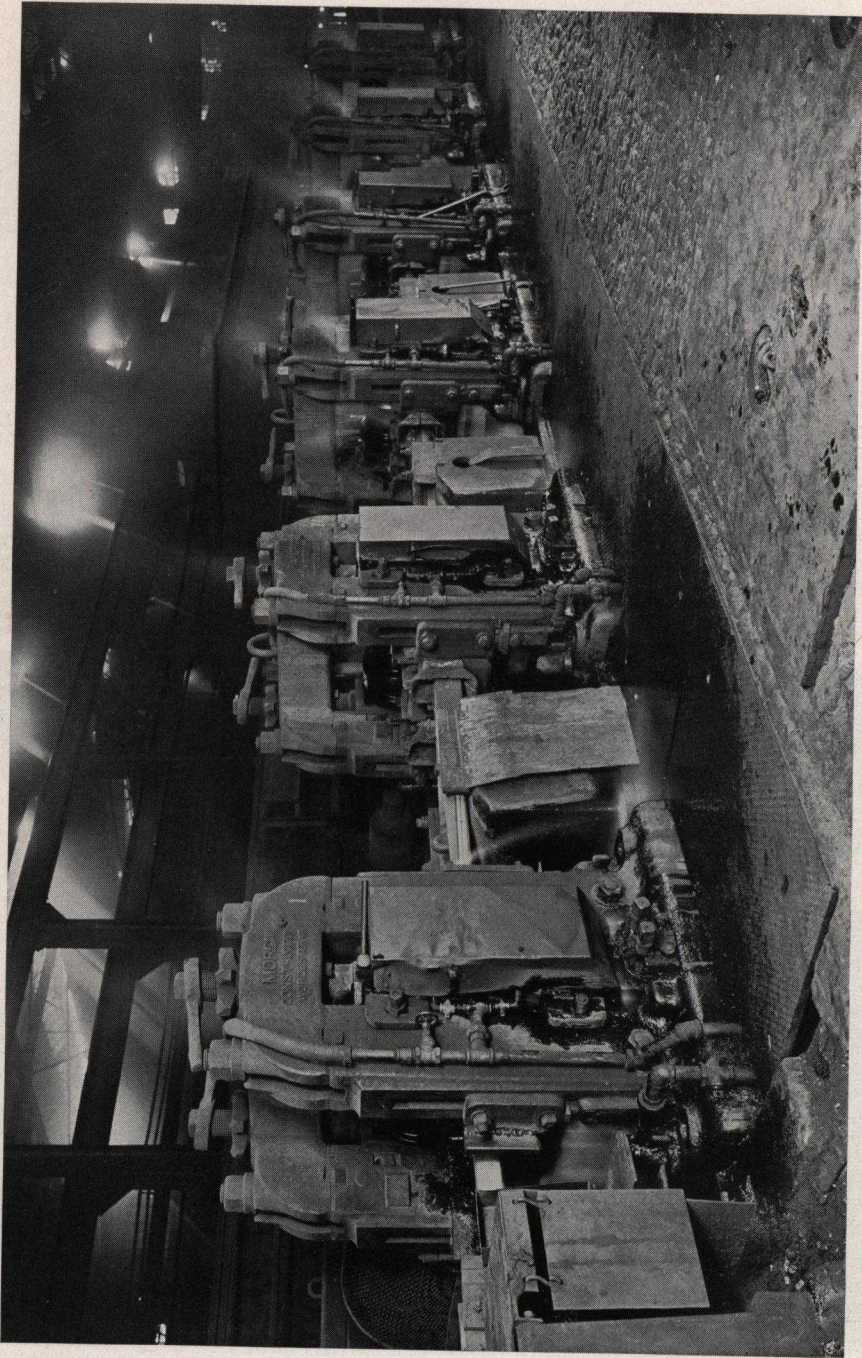
S.A.E. No.	C.	Mn.	P.(max.)	S.(max.)	Si.
9255	0.50-0.60	0.60-0.90	0.040	0.050	1.80-2.20
9260	0.55-0.65	0.60-0.90	0.040	0.050	1.80-2.20

Corrosion and Heat-Resisting Alloys

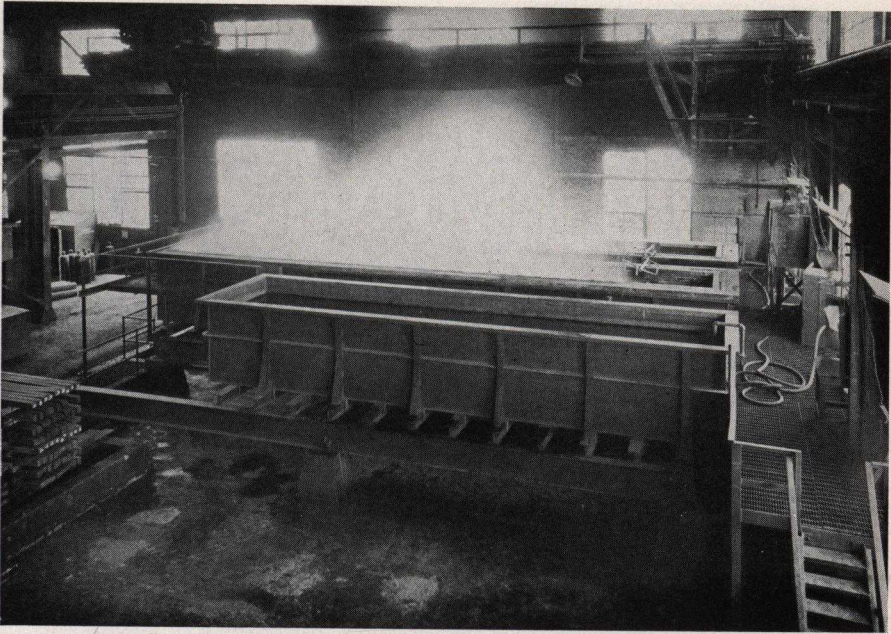
S.A.E. No.	C.(max.)	Mn.(max.)	P.(max.)	S.(max.)	Si.(max.)	Nickel	Chromium
30905	0.08	0.20-0.70	0.030	0.030	0.75	8.00-10.00	17.00-20.00
30915	0.09-0.20	0.20-0.70	0.030	0.030	0.75	8.00-10.00	17.00-20.00
51210	0.12	0.60	0.030	0.030	0.50	.....	11.50-13.00
X51410	0.12	0.60	0.030	0.15-0.50	0.50	.....	13.00-15.00
51335	0.25-0.40	0.60	0.030	0.030	0.50	.....	12.00-14.00
51510	0.12	0.60	0.030	0.030	0.50	.....	14.00-16.00
51710	0.12	0.60	0.030	0.030	0.50	.....	16.00-18.00



Section of chipping beds and machine for preparing surfaces of blooms by removing surface imperfections



Continuous billet mill



Pickling tanks for blooms and billets to clean surfaces for inspection



Billet yard. Each billet identified by heat number, weight and colored marking denoting grade

TYPES OF ALLOY AND SPECIAL PURPOSE CARBON STEELS

THE charts presented in the following pages show the physical properties of the various types of steel in the "as-rolled" or "natural," "annealed," "normalized," and "quenched and drawn" conditions.

It must be remembered in making use of these data that the results represent average physical properties. They are not the maximum obtainable, nor the minimum which may be anticipated. They are offered for guidance only.

It must be further understood that the size of the section has a pronounced effect on results and that these charts in every case represent results obtained from a one-inch round bar in the condition designated at the bottom of each chart. The tensile tests were made by machining a 0.505x2 inch gage size specimen from the axis of the bar. If the specimen is the original bar size and the elongation is measured over 8 inches, a lower percentage of elongation is naturally to be expected.

The Brinell, Rockwell and Scleroscope values shown on these charts are results of tests made on the tensile bars and are therefore representative of the internal hardness rather than the surface or skin hardness.

Impact tests such as Izod or Charpy are available on request for these different type steels but have not been included in the charts because of the possibility of misinterpretation due to variations in making this test, such as the methods, degree of finish of notch, type of machine, and the change of values in some alloy grades dependent on the rate of cooling from the drawing temperature.



Removing imperfections in small billets by chipping



One of the batteries of billet grinders to remove surface imperfections

SPECIAL CARBON STEELS

THERE are grades of carbon steels for special purposes which are usually made in the alloy mill and under alloy steel practice and control.

In addition to the basic open hearth products there are also the acid open hearth and the electric furnace steels for special purposes with unusual ranges of composition. Edge-tools, of open hearth steel with medium high carbon ranges, such as woodworking chisels, auger bits, saw steel and cutting tools for stone and metals, such as cold chisels, picks, digging bars, and so forth, fall in this classification.

The file steels are found in the highest carbon ranges. These types of steels are processed throughout with the utmost care in order to insure a good surface, with minimum decarburization and segregation, resulting in hard wearing or cutting surfaces after heat treatment.

Commercially, steels are considered in the carbon grade so long as the mean of the manganese range does not exceed 1.50 per cent.

Some of the types of steel with manganese on the high side carry sulphur that is considerably above normal to improve machinability. These steels, besides possessing free-cutting properties, develop an excellent combination of physical qualities in the heat-treated condition.

For information and comparison, a few of the charts of the carbon and lower manganese steels are presented.

S. A. E. RECOMMENDED HEAT TREATMENT (Revised 1935)

S.A.E. No.	Treatment Number	Normalize	Anneal	Quench	Draw
1025	{	I	.....	1575-1650 H ₂ O	To desired hardness
X1025					
1030	{	II	1700-1800-M	1575-1650 H ₂ O	To desired hardness
1035					
1040	{	I	.....	1525-1575 oil or H ₂ O	To desired hardness
X1040					
	{	II	1650-1750-M	1525-1575 oil or H ₂ O	To desired hardness

S. A. E. Recommended Heat Treatment (Continued)

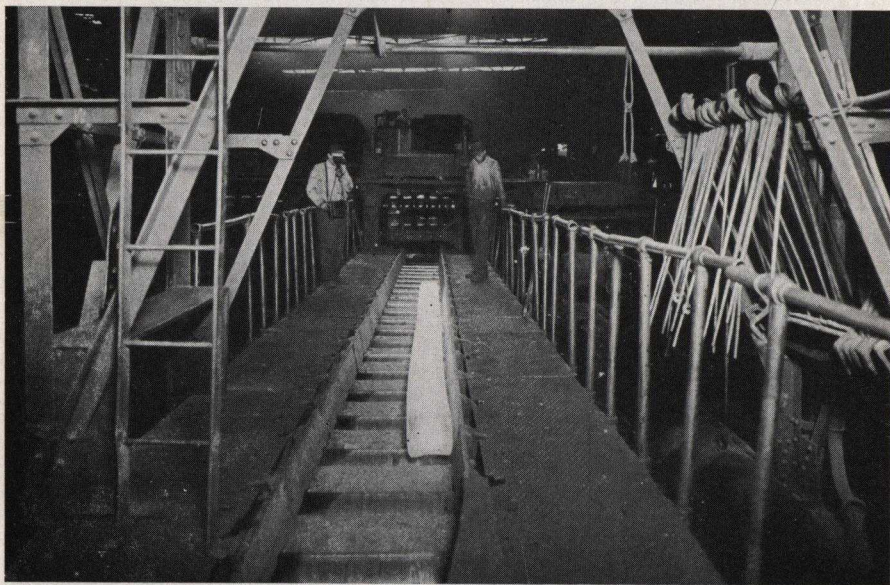
S. A. E. No.	Treatment Number	Normalize	Anneal	Quench	Draw
1045}					
X1045}	I	.....	.....	1450-1550 oil or H ₂ O	To desired hardness
1050}	II	1600-1700	.....	1475-1525 oil or H ₂ O	To desired hardness
X1050}					
1055	I	Yes, or	Yes-M	1450-1550 oil or H ₂ O	To desired hardness
X1055	I	Yes, or	Yes-M	1500-1550 oil	To desired hardness
1060}					
1065}	I	Yes, or	Yes-M	1450-1550 oil	To desired hardness
X1065}					
1070}					
1075	I	Yes, or	Yes-M	1450-1500 oil	To desired hardness
1080	I	Yes	Yes-M	1450-1500 oil	To desired hardness
1085	I	Yes	Yes-M	1400-1500 oil	To desired hardness
1090}	I	Yes	Yes-M	1430-1500 oil, H ₂ O, brine	To desired hardness
1095}	II*	.....	.....	1500-1600 oil	750-900
X1330	I	.....	.....	1525-1575 oil or H ₂ O	To desired hardness
	II	1650-1750-M	.....	1525-1575 oil or H ₂ O	To desired hardness
X1335	I	.....	.....	1500-1550 oil or H ₂ O	To desired hardness
X1340}	II	1650-1750-M	.....	1500-1550 oil or H ₂ O	To desired hardness

*For leaf springs.

When preference is given in quenching media the shape and section shall be the deciding factor.

M=Machine.

For carburizing or activated bath treatments of S. A. E. 1010, 1015, X1015, 1020, X1020, 1025, X1025, 1030, 1115, 1120, X1314 and X1315, see article on Carburizing Steels, page 95.



Three-high bar mill

PHYSICAL PROPERTIES CHART

S. A. E. 10-15
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.10% /20	.30% /60	.045	.055				

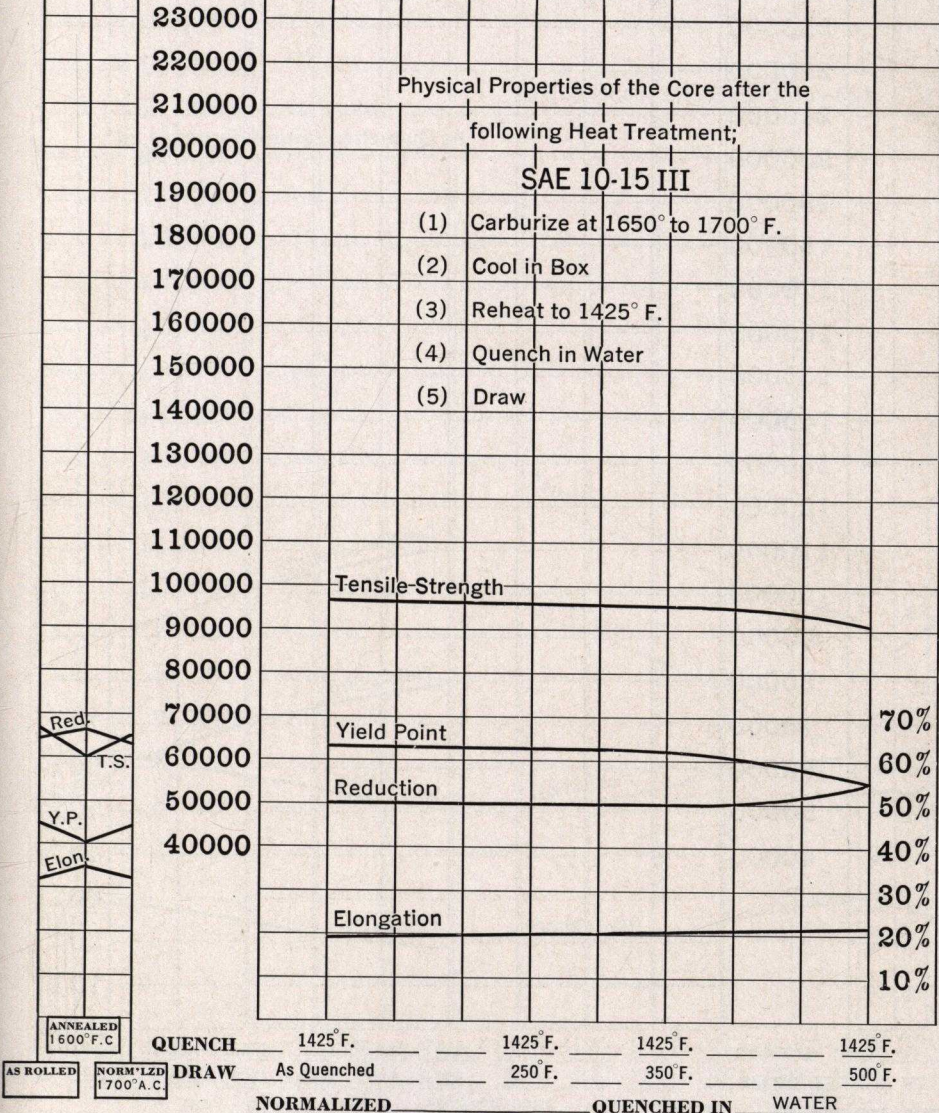
10-15

137	128	134	S. ROCK.	C67			C65		C63		C60
16	14	16	S. SHORE	89			88		85		80
B75	B70	B74	I. BRIN.	201			201		197		183
			I. SHORE	26			26		25		22
			I. ROCK.	C16			C16		C15		B90

Physical Properties of the Core after the
following Heat Treatment;

SAE 10-15 III

- (1) Carburize at 1650° to 1700° F.
- (2) Cool in Box
- (3) Reheat to 1425° F.
- (4) Quench in Water
- (5) Draw



PHYSICAL PROPERTIES CHART

S. A. E. 10-40
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.35/.45	.60/.90	.045	.055				

10-40

187	167	192	BRIN.					255	235	217	207	197	187
23	19	24	SHORE					35	32	29	27	25	23
B91	B85	B92	ROCK.					C25	C22	C19	C17	B93	B91

230000
220000
210000
200000
190000
180000
170000
160000
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000

As Quenched Brinell Hardness 534

Tensile Strength

Yield Point

Reduction

Elongation

70%
60%
50%
40%
30%
20%
10%

T.S.

Y.P.

Red.

Elong.

ANNEALED
1450° F. C.

QUENCH

DRAW

AS ROLLED

NORM'LZD
1650° A. C.

1525° F. 1525° F. 1525° F. 1525° F. 1525° F. 1525° F.
800° F. 900° F. 1000° F. 1100° F. 1200° F. 1300° F.
NORMALIZED 1650° A. C. QUENCHED IN WATER

PHYSICAL PROPERTIES CHART

.80 CARBON STEEL

(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

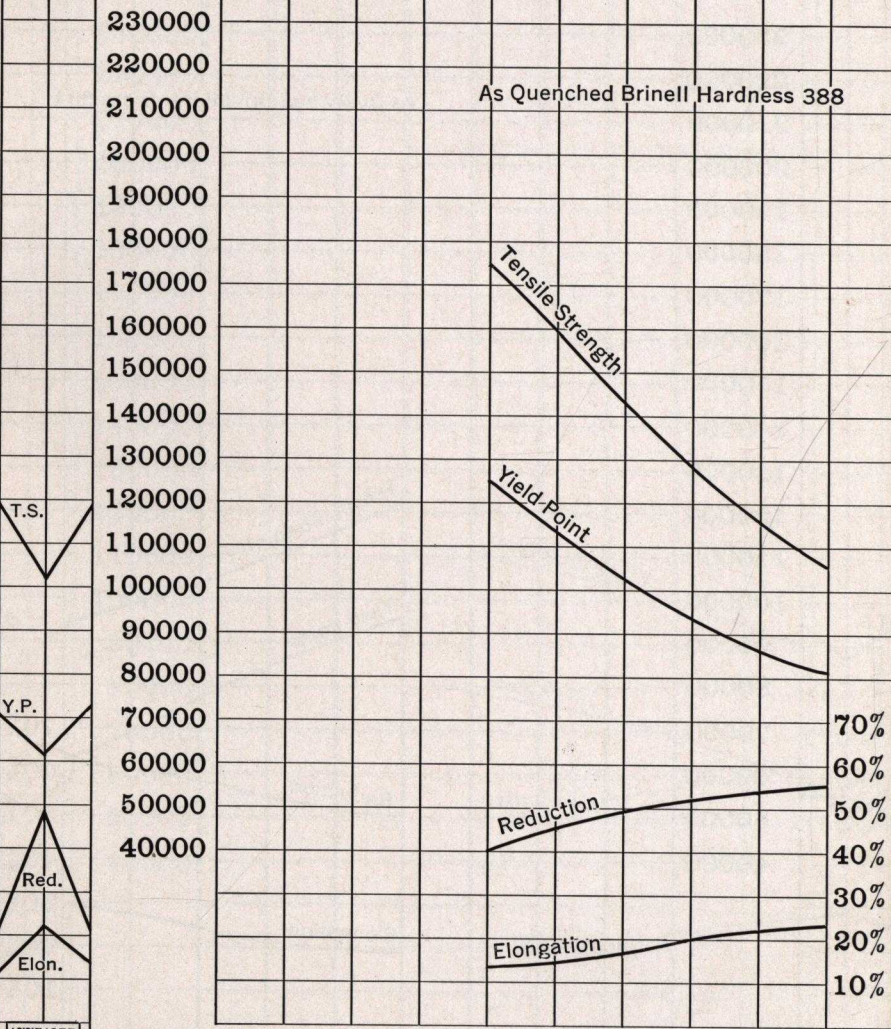
C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.75/90	.30/50	.04	.05	.15/25			

.80 CARBON

248	197	248
34	25	34
C24	C15	C24

BRIN.
SHORE
ROCK.

363	331	293	262	235	217
48	44	39	36	32	28
C37	C34	C30	C26	C22	C19



ANNEALED 1450° F. C. QUENCH 1500° F. 1500° F. 1500° F. 1500° F. 1500° F. 1500° F. 1500° F.
AS ROLLED NORM'LZD 1650° A.C. DRAW 800° F. 900° F. 1000° F. 1100° F. 1200° F. 1300° F.
NORMALIZED 1650° A.C. QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

.80 CARBON STEEL

(Average Values)

.80
CARBON

1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.75/90	.30/50	.04	.055	.15/25			

248	197	248	BRIN.					388	341	293	269	241	223
34	25	34	SHORE					49	44	39	36	33	29
C24	C15	C25	ROCK.					C39	C35	C30	C27	C23	C20

230000

220000

210000

200000

190000

180000

170000

160000

150000

140000

130000

120000

110000

100000

90000

80000

70000

60000

50000

40000

As Quenched Brinell Hardness 601

Tensile Strength

Yield Point

Reduction

Elongation

70%
60%
50%
40%
30%
20%
10%

T.S.

Y.P.

Red.

Elong.

ANNEALED
1450° F.C.

QUENCH

1475° F. 1475° F. 1475° F. 1475° F. 1475° F. 1475° F.

AS ROLLED

NORM'LZD
1650° A.C.

DRAW

800° F. 900° F. 1000° F. 1100° F. 1200° F. 1300° F.

NORMALIZED

1650° A.C.

QUENCHED IN

WATER

PHYSICAL PROPERTIES CHART

S. A. E. 10-95
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

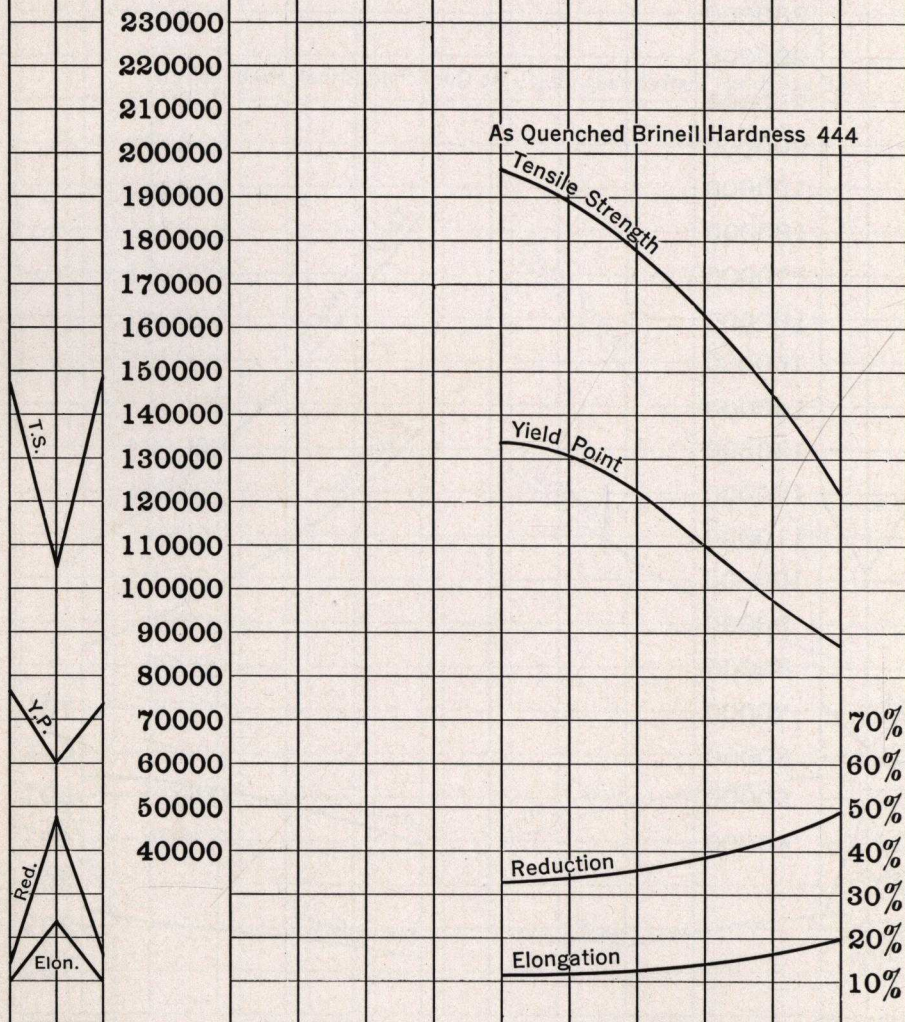
C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.90/ 1.05	.25/ .50	.04	.055				

10-95

293 40 C30	201 26 C16	285 39 C29
------------------	------------------	------------------

BRIN.
SHORE
ROCK.

388 50 C39	375 49 C38	363 48 C37	331 44 C34	293 40 C30	248 34 C24
------------------	------------------	------------------	------------------	------------------	------------------



AS ROLLED ANNEALED 1450°F.C. QUENCH 1475°F. 1475°F. 1475°F. 1475°F. 1475°F. 1475°F.
 DRAW 800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.
 NORMALIZED 1650°A.C. QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

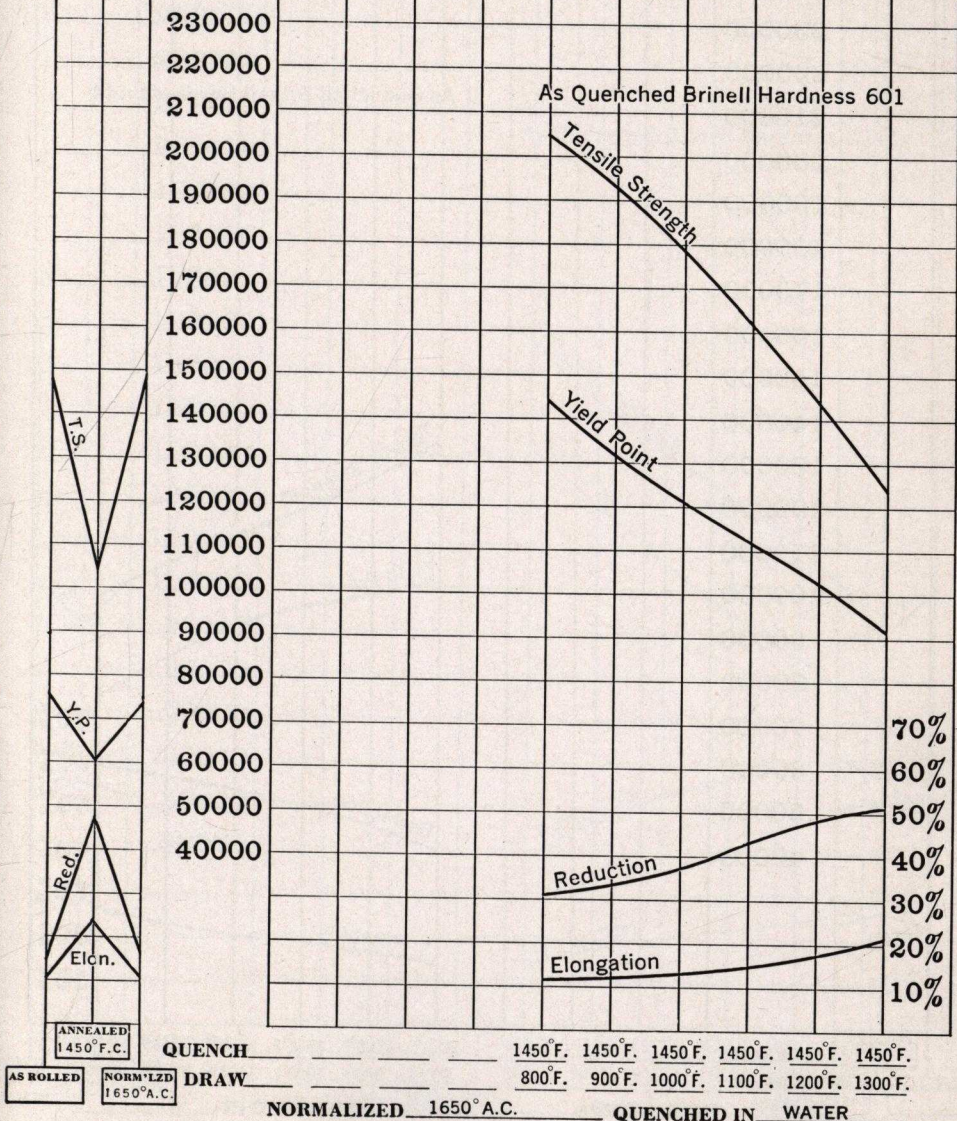
S. A. E. 10-95
(Average Values)

10-95

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.90	.25	.04	.055				
1.05	.50						

293	201	285	BRIN.					401	388	363	331	293	248
40	26	39	SHORE					52	50	48	44	40	34
C30	C16	C29	ROCK.					C41	C37	C35	C34	C30	C24



PHYSICAL PROPERTIES CHART**.33 CARBON, 1.20 MANGANESE STEEL**

(Average Values)

1" Dia. **SIZE TREATED**.505" x 2" **SIZE TESTED****.33 CARBON
1.20 MANG.**

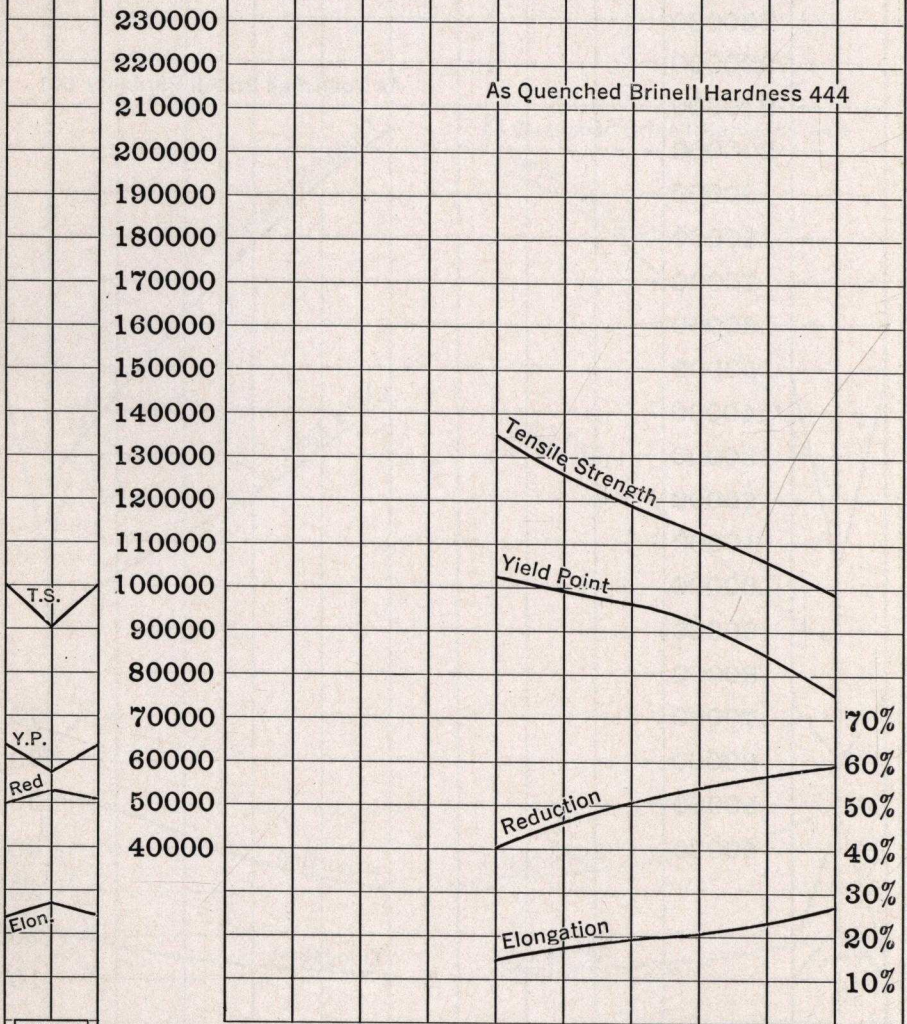
C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.28/.38	1.00/1.40	.04	.05	.10/.25			

201	179	201
27	21	27
C16	B88	C16

**BRIN.
SHORE
ROCK.**

277	255	235	223
37	35	31	30
C28	C25	C22	C20

212	201
28	27
C18	C16



PHYSICAL PROPERTIES CHART

.33 CARBON, 1.20 MANGANESE STEEL

(Average Values)

1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.
.28/38	1.00/1.40	.04	.05	.10/25		

.33 CARBON
1.20 MANG.

201	179	201	BRIN.					311	285	262	248	223	197
27	21	27	SHORE					41	38	35	33	30	26
C16	B88	C16	ROCK.					C32	C29	C26	C24	C20	C15

230000
220000
210000
200000
190000
180000
170000
160000
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000

As Quenched Brinell Hardness 534

Tensile Strength
Yield Point

Reduction

Elongation

70%
60%
50%
40%
30%
20%
10%

Y.S.

Y.P.
Red.

Elong.

ANNEALED
1450°F. C.

QUENCH

1552°F. 1552°F. 1552°F. 1552°F. 1552°F. 1552°F.

AS ROLLED

NORMALIZED
1650°A.C.

DRAW

800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.

NORMALIZED 1650°A.C.

QUENCHED IN WATER

MEDIUM MANGANESE STEELS

MANGANESE when used as an alloy in steel imparts improved strength in the natural or "as-rolled" condition, and in the heat-treated condition improves the combination of strength and ductility, provided the section is not too heavy. For the heavier sections in the heat-treated condition the richer alloy steels respond more satisfactorily.

Steels commercially classed as manganese steels have the mean of the range over 1.50 per cent manganese; below this they are classed as carbon steels. The carbon content varies depending on the application. The manganese steels fall in the 13xx series.

In the lower carbon ranges (up to 0.25 per cent C), they are used in the carburized condition in such parts as steering worms, crankshafts, pins, bushings, miscellaneous machine parts, gages, journals, shafting, washing and refrigerator machinery parts, small gears and pinions, the latter being the principal applications.

As the carbon content increases from 0.25 to 0.35 per cent, these steels are used for general machine parts both treated and untreated, because they afford higher physical properties than carbon steels of the same carbon content. In general, it is preferable not to place any alloy steel of the types referred to in this book in service without annealing, normalizing, normalizing and drawing, or quenching and drawing, since such heat treatment is required to bring out the full benefits of the alloy constituents.

It should also be remembered that manganese steels, containing over 0.35 per cent carbon, should be oil quenched rather than water quenched because of the danger of cracking due to the combination of relatively high manganese and increased carbon content.

A very popular group of steels, especially in the automotive industry, is the group of this series in the 0.30 to 0.40 per cent carbon range. These are always put in service in the heat-treated condition for such parts as main bearing bolts, engine bolts, connecting rod bolts, studs, timing chain links, brake drums,

flange yokes, sleeves, stud and ball yokes, flanges and so on. In industry in general, outlets for this grade of steel include pressure cylinders, logging and road machinery, gears, shafting, axles, pistons, miscellaneous bolts and studs, and many other machine parts.

The steels with a carbon content of 0.45 to 0.60 per cent are widely used in making oil-hardened gears, axles, shafts, grinding balls and for other uses where high strength and fair ductility are required.

The Bethlehem "33" series steels develop a good combination of physical properties and are so balanced chemically that good machinability is obtained. This type is furnished in three grades; A, B, and C. Grade 33A has 0.12 to 0.20 per cent carbon; grade 33B contains 0.25 to 0.35 per cent carbon; and grade 33C ranges between 0.35 and 0.45 per cent carbon. Grade 33A is a water-quenching and carburizing steel; 33B may be either oil or water-quenched; 33C is an oil-quenching steel but good results can be obtained by water quenching when the parts treated are not intricate in shape.

S. A. E. RECOMMENDED HEAT TREATMENT (Revised 1935)

S. A. E. Treatment No.	Number	Normalize	Anneal	Quench	Draw
T1330	I	.....	.....	1525-1575 oil or H ₂ O	To desired hardness
	II	1650-1750-M	.....	1525-1575 oil or H ₂ O	To desired hardness
T1335 T1340	I	.....	.....	1500-1550 oil	To desired hardness
	II	1650-1750-M	.....	1525-1575 oil	To desired hardness
T1345 T1350	I	.....	.....	1450-1550 oil	To desired hardness
	II	Yes	Yes-M	1450-1500 oil	To desired hardness

When choice is given in quenching media the shape and section shall be the deciding factor.
M=Machine.

PHYSICAL PROPERTIES CHART

S. A. E. T13-30

(Average Values)

1" Dia. **SIZE TREATED**

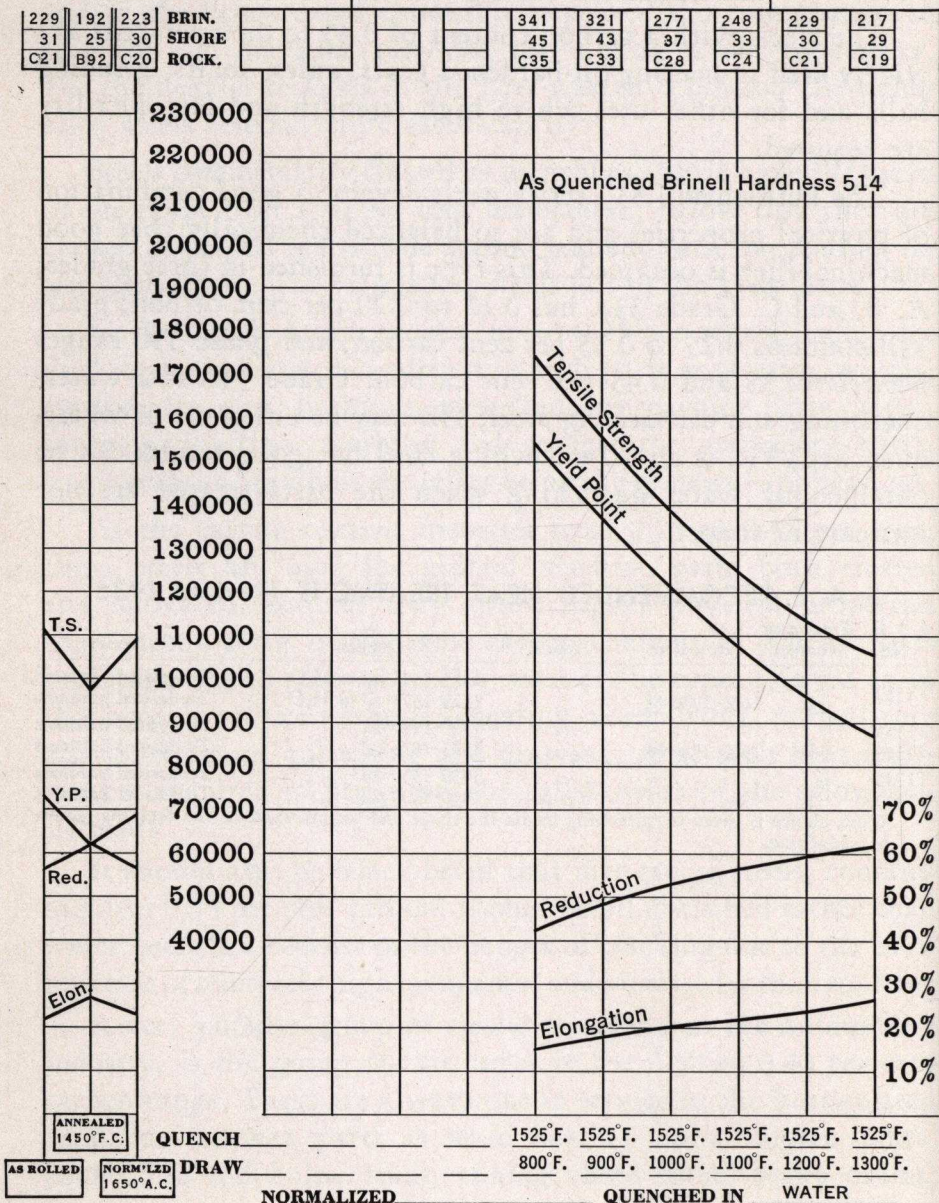
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.25/.35	1.60/1.90	.04	.05	.15/.30			

T13-30

229	192	223
31	25	30
C21	B92	C20

341
45
C35



PHYSICAL PROPERTIES CHART

S. A. E. T13-40

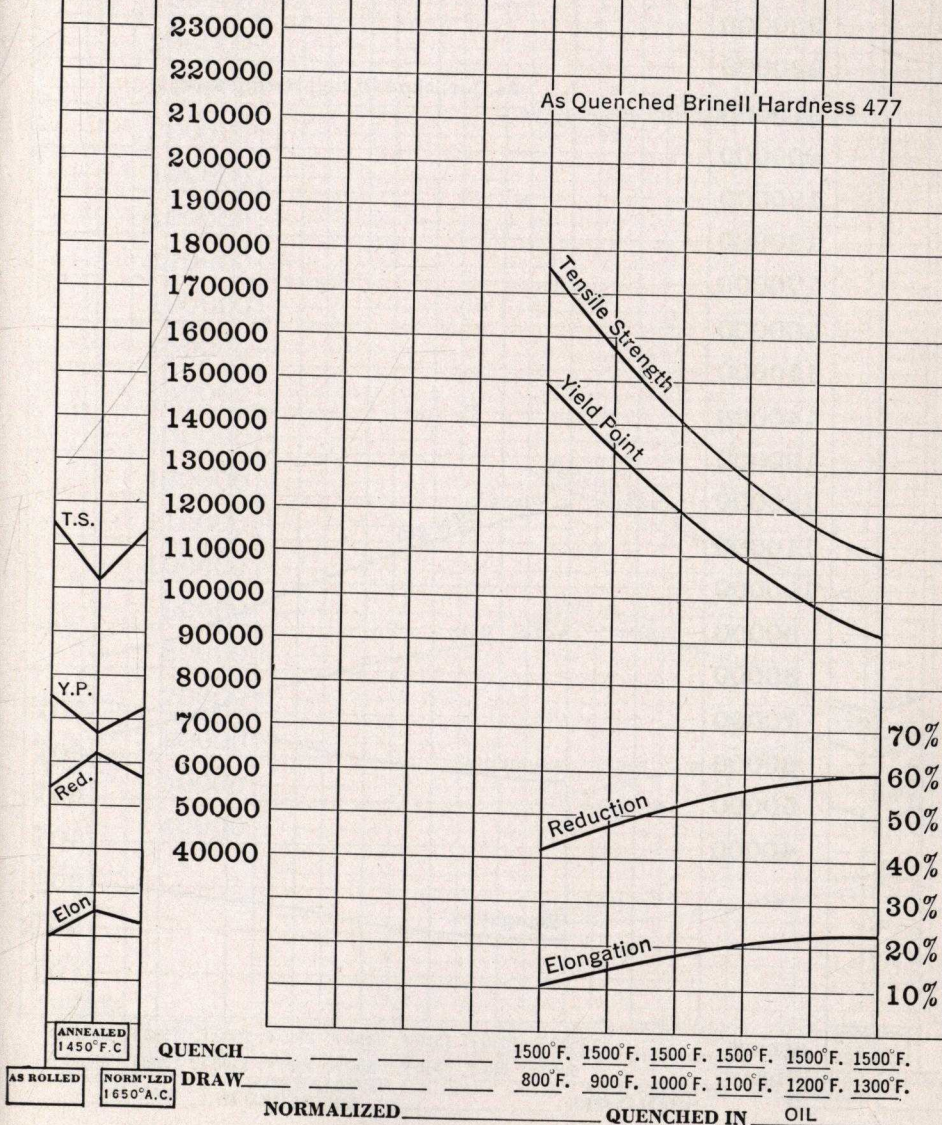
(Average Values)

1" Dia. **SIZE TREATED**

.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.35/45	1.60/1.90	.04	.05	.15/30			

T13-40

[illegible]

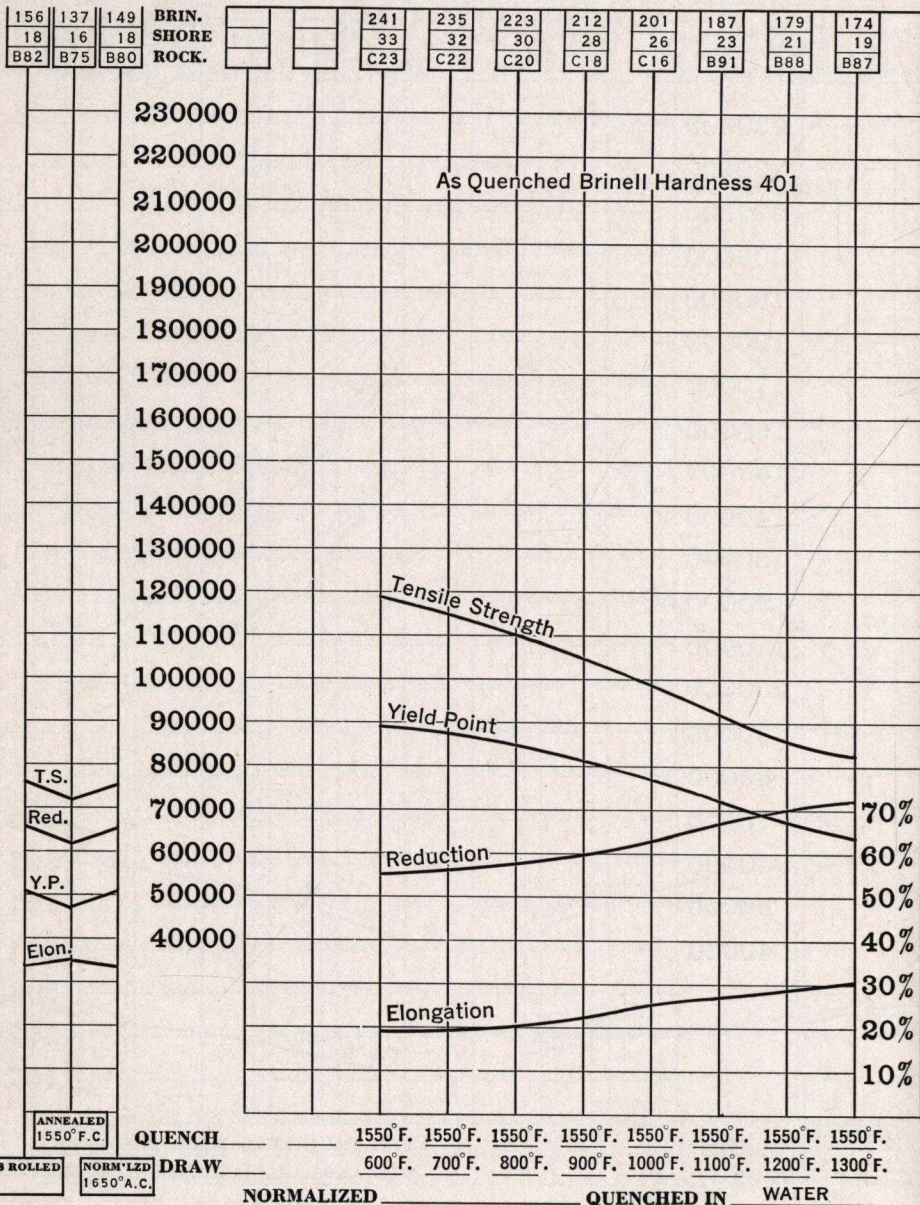
PHYSICAL PROPERTIES CHART

"33A" STEEL
(Average Values)

33A

1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED

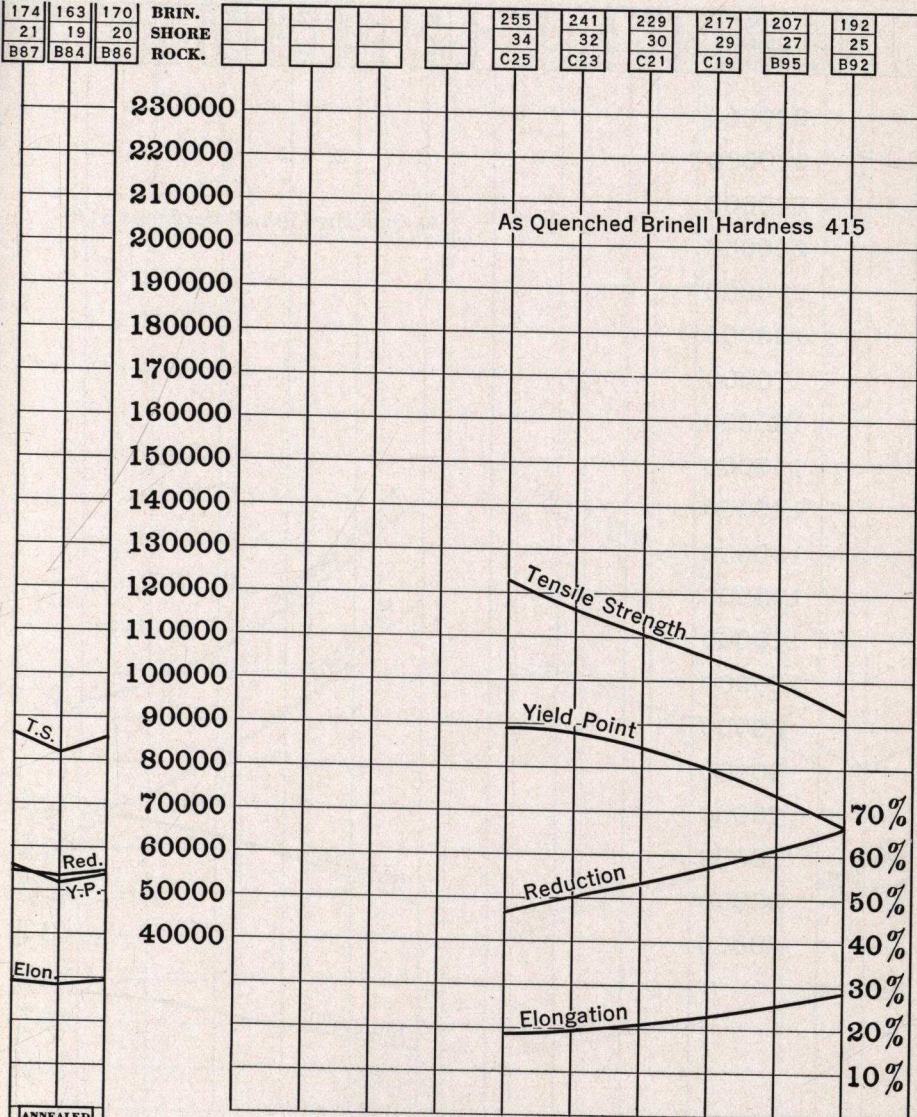


PHYSICAL PROPERTIES CHART

"33B" STEEL
(Average Values)

33B

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED



PHYSICAL PROPERTIES CHART

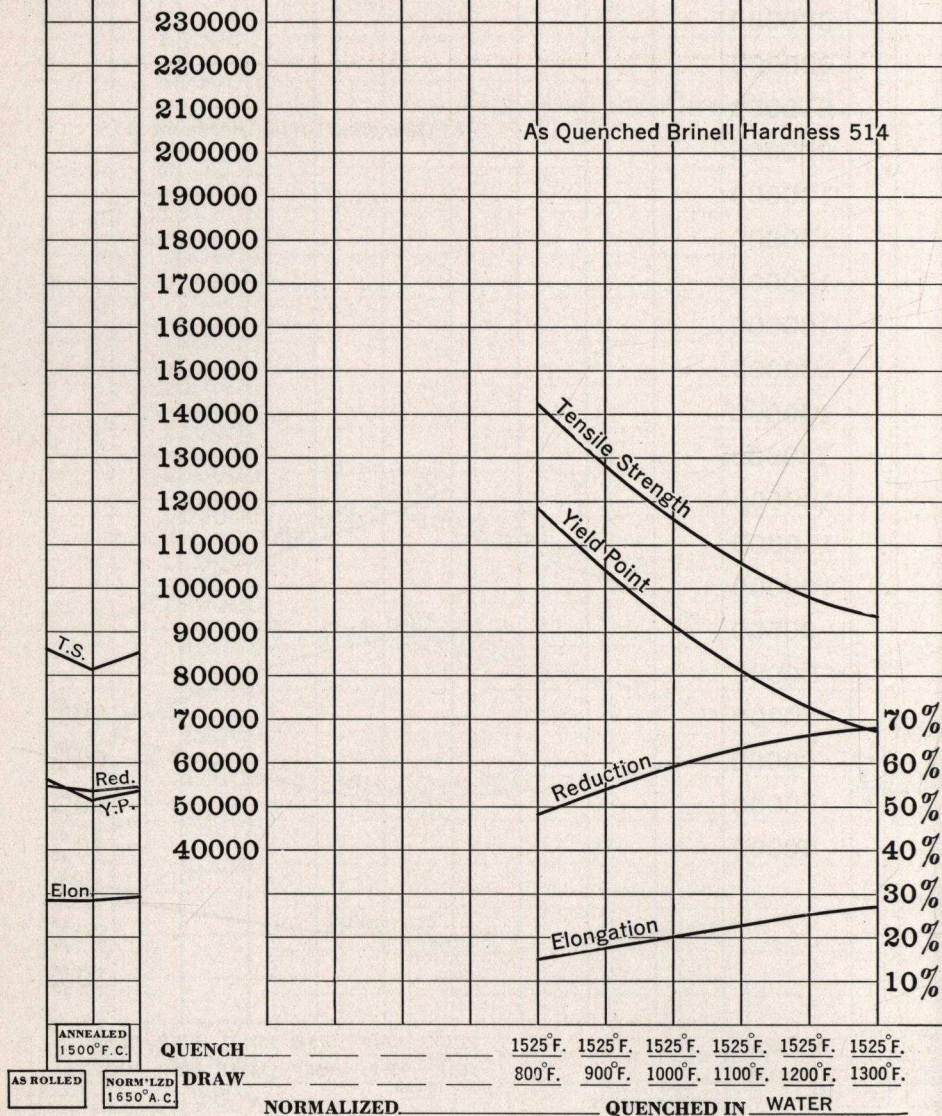
"33B" STEEL
(Average Values)

33B

1" Dia. SIZE TREATED

.505"x 2" SIZE TESTED

174	163	170	BRIN.					293	269	248	217	201	192
21	19	20	SHORE					40	37	34	29	26	24
B87	B84	B86	ROCK.					C30	C27	C24	C19	C16	B92



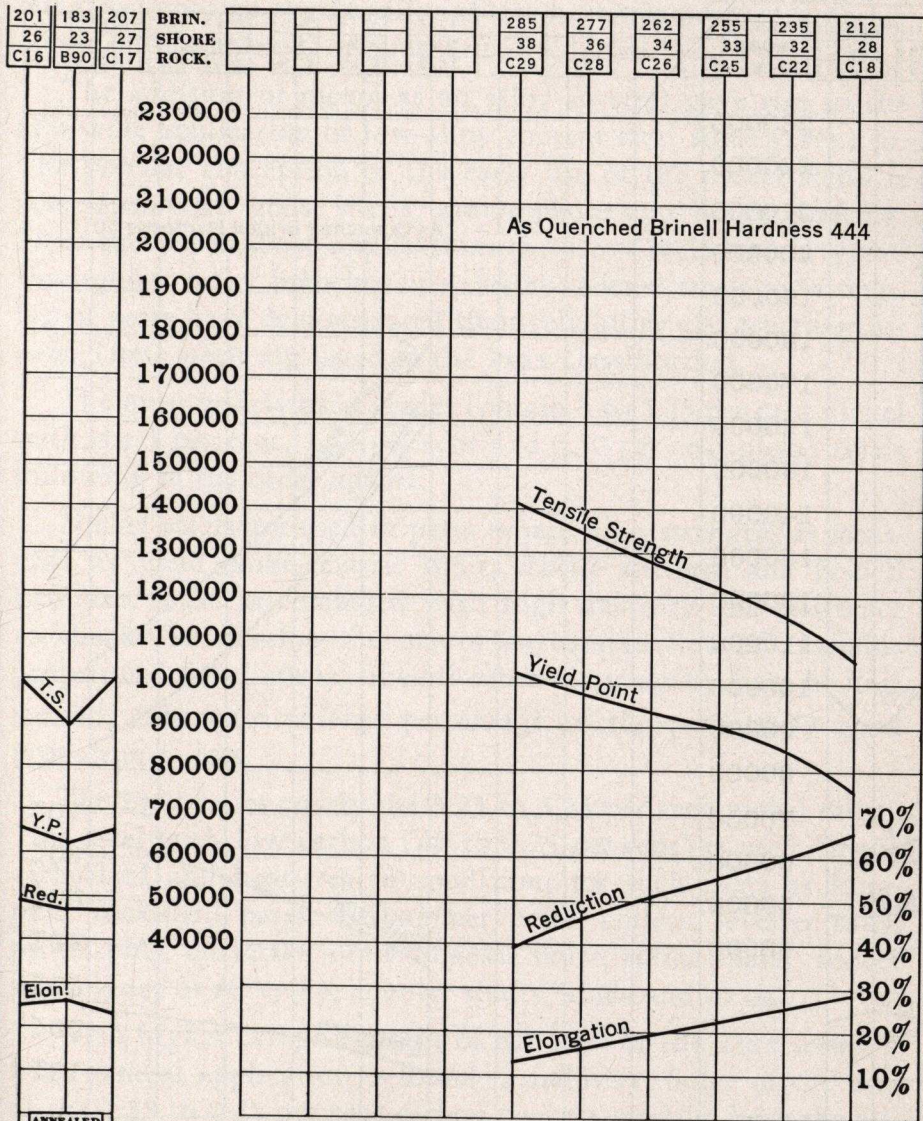
PHYSICAL PROPERTIES CHART

"33C" STEEL
(Average Values)

33C

1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED



☐ AS ROLLED ☐ ANNEALED 1450°F.C. ☐ QUENCH _____ 1550°F. 1550°F. 1550°F. 1550°F. 1550°F. 1550°F.
☐ NORM'LZD 1625°A.C. ☐ DRAW _____ 800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.
 NORMALIZED 1625°A.C. QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

"33C" STEEL
(Average Values)

33C

1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED

201	183	207
26	23	27
C16	B90	C17

BRIN.
SHORE
ROCK.

375
48
C38

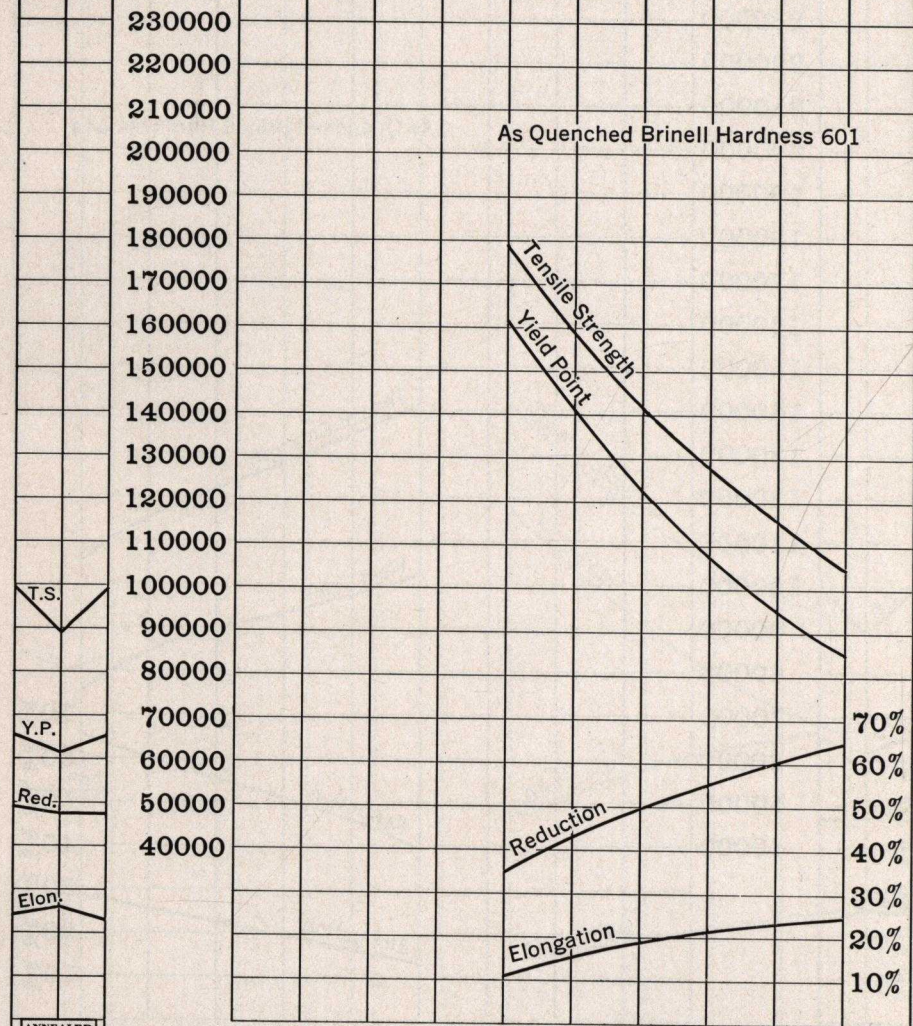
331
43
C34

285
39
C29

262
36
C26

241
33
C23

212
28
C18



ANNEALED
1450° F.C.

QUENCH

1500° F. 1500° F. 1500° F. 1500° F. 1500° F. 1500° F.

AS ROLLED

NORM. L'D
1625° A.C.

DRAW

800° F. 900° F. 1000° F. 1100° F. 1200° F. 1300° F.

NORMALIZED 1625° A.C.

QUENCHED IN WATER

NICKEL STEELS

NICKEL as an alloy goes into solution in iron (ferrite) and not only has the effect of imparting greater strength but also improves the ductility of any heat-treated part, whether annealed, normalized, or quenched and drawn.

The addition of nickel as an alloy in steel gave rise to the first wide application of low-alloy content steel some years ago. The popular conception of the early use of the nickel steels is associated with guns, shells, armor plate, and heavy shafting. From these specialized applications the use of nickel steels spread throughout many branches of industry. Nickel steels for a number of years have demonstrated their reliability and trustworthiness. These steels are listed in the 2xxx classification.

The most widely used grades contain 3 to 3.75 per cent nickel with the 5 per cent, 1.50 per cent and 0.50 per cent nickel steels following in the order named.

Nickel steels are used in parts where high strength, as measured by yield point, elastic limit, tensile strength and Brinell hardness, must be combined with high ductility and resistance to shock. To develop the maximum combination of available properties, nickel steels, like all other alloy steels, must be heat treated, otherwise a large percentage of the potentially good properties is lost.

The 23xx series covers the 3.25 to 3.75 per cent nickel range. This steel with low carbon (up to 0.25 per cent) is used, in the carburized and heat-treated condition, for such parts as king-pins, rock-drill parts, air-hammer parts, collets, leveller rolls, piston pins, universal joints, shackle bolts, spline shafts, rocker arms, gears of all types, counter shafts, studs and so on.

With higher carbon content of the steel of the 23xx series, a wide general application is found in industry. Some of the uses of the 0.35 to 0.45 per cent carbon content steels in both the oil- and water-hardened condition, include heavy-duty shafts, stub shafts, set screws, studs, bolts, steering knuckles, drive shafts,

airplane crankshafts, rocker arms, engine bolts and studs, connecting rods and so on.

With carbon contents averaging over 0.40 per cent, nickel steels of the 23xx series become an oil-hardening type and are used generally for parts involving high strength such as heavy-duty gears, shafts, axles, spindles, and pinions.

The 25xx series containing 5 per cent nickel are carburizing. They combine excellent wearing surface with an extremely strong, ductile, and shock resistant core especially useful for unusually heavy service such as truck or bus gears, spline shafts, piston pins, counter shafts, drive gears, airplane engine parts and so forth. In the heat-treated condition without carburization, because of its toughness, it is used in such parts as piston rods for hammers, turbine blading, etc.

The lower nickel steels, 0.50 and 1.50 per cent nickel, listed in the 20xx and 21xx series, are generally used with lower carbon content in the carburized and treated condition for such parts as service gears. They have greater toughness and better depth hardening properties than the carbon steels under parallel conditions. They are also used for such parts as engine bolts, staybolts, rivets, locomotive spring rigging, and so on.

Nickel steel of the following general composition is used for highly stressed and reciprocating parts for locomotives. This steel is usually put in service in the normalized and annealed condition but in the case of locomotive axles some roads quench and draw this type of steel.

Carbon to suit, within.....	0.20 to 0.35 per cent
Manganese.....	0.70 to 1.00 per cent
Silicon.....	0.15 to 0.30 per cent
Nickel.....	2.50 to 3.00 per cent

S. A. E. RECOMMENDED HEAT TREATMENT (Revised 1935)

S. A. E. No.	Treatment Number	Normalize	Anneal	Quench	Draw
2330}	I	.....	.....	1450-1500	To desired hardness
2335}	II	Yes, or	Yes-M	1450-1500	To desired hardness
2340}	I	.....	.....	1425-1475 oil	To desired hardness
2345}	II	Yes	Yes-M	1425-1475 oil	To desired hardness
2350}	I	Yes	Yes-M	1425-1475 oil	To desired hardness*

*For gears 375-425° F.

M = Machine

For carburizing or activated bath treatments of S. A. E. 2015, 2115, 2315, 2320 and 2515, see article on Carburizing Steels, page 95.

PHYSICAL PROPERTIES CHART

S. A. E. 23-15
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

23-15

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.10/20	.30/60	.04	.05	.15/30	3.25/3.75		
C63			C61		C60		C58
80			78		76		72
285			277		277		269
38			37		37		36
C29			C28		C28		C27

230000
220000
210000
200000
190000
180000
170000
160000
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000

Physical Properties of the Core after
the following Heat Treatment;

SAE 23-15 II

- (1) Carburize at 1650° to 1700°
- (2) Cool in Box
- (3) Reheat to 1450°
- (4) Quench in Oil
- (5) Draw

Tensile Strength

Yield Point

Reduction

Elongation

70%
60%
50%
40%
30%
20%
10%

T.S.

Red.

Y.P.

Elong.

ANNEALED
1600°F.C.

QUENCH 1450°F. 1450°F. 1450°F. 1450°F.
As Quenched 250°F. 350°F. 500°F.

NORMALIZED

QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

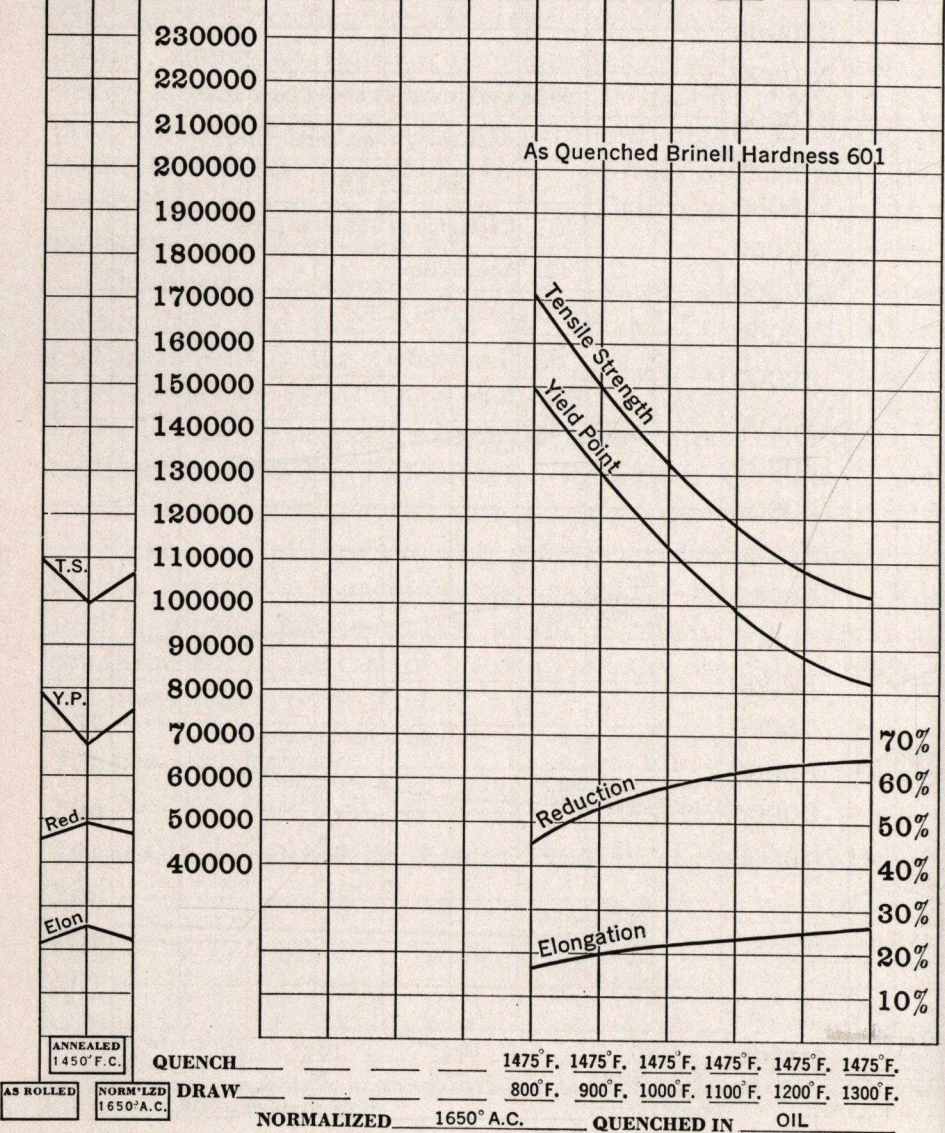
S. A. E. 23-40
(Average Values)

23-40

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.35/45	60/90	.04	.05	.15/30	3.25/3.75		

229	201	223	BRIN.					341	302	269	241	212	201
30	26	29	SHORE					45	41	37	33	28	26
C21	B93	C20	ROCK.					C35	C31	C27	C23	C18	C16



PHYSICAL PROPERTIES CHART

S. A. E. 25-15
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
10/20	.30/60	.04	.05	.15/30	4.75/5.25		

25-15

S. ROCK.	C58	C57	C55	C53
S. SHORE	78	74	69	67
I. BRIN.	363	363	352	341
I. SHORE	47	47	45	43
I. ROCK.	C37	C37	C36	C35

Physical Properties of the Core after
the following Heat Treatment;
SAE 25-15 I
(1) Carburize at 1650° to 1700°
(2) Cool in Box
(3) Reheat to 1425°, Quench in Oil
(4) Draw

Tensile Strength

Yield Point

Reduction

Elongation

T.S.

Red.

Y.P.

Elong.

70%
60%
50%
40%
30%
20%
10%

ANNEALED
1500° F. C.

NORM'LZD
1650° A. C.

QUENCH 1425 F. 1425° F. 1425° F. 1425° F.
DRAW As Quenched 250 F. 350 F. 500° F.
NORMALIZED QUENCHED IN OIL

AS ROLLED

NICKEL-CHROMIUM STEELS

CHROMIUM is essentially a hardening element when alloyed with steel. The combination of nickel and chromium therefore produces a steel having the benefits of the added strength of both alloys, chromium being the more effective in increasing the hardness penetration in the heat-treated condition. The ductility is improved by the nickel.

The general acceptance of nickel as an alloying element in steel having been established, there followed the combination of nickel and chromium. This grade, like the nickel types, was used originally in ordnance work as in shells, armor plate, and torpedo air flasks. As with nickel steels, the use of nickel-chromium steels rapidly broadened with the development of the automobile. They are now generally used throughout industry where parts are subjected to unusual operating conditions.

The nickel-chromium steels are in the 3xxx series and are then subdivided as follows: the 31xx series, having 1.00 to 1.50 per cent nickel and 0.45 to 0.75 per cent chromium; the 32xx series, containing 1.50 to 2.00 per cent nickel and 0.90 to 1.25 per cent chromium; the 33xx series, with 3.25 to 3.75 per cent nickel and 1.25 to 1.75 per cent chromium; and the 34xx series, containing 2.75 to 3.25 per cent nickel and 0.60 to 0.95 per cent chromium. Of these grades, the 31xx and 32xx series are more widely used than the 33xx and 34xx steels.

The original Bethlehem "Mayari" steel is a type of steel similar to the present 31xx series. This grade is produced in carbon ranges varying from 0.10 to 0.70 per cent. Like other alloy steels, up to 0.25 per cent carbon, this type is generally used for carburized parts such as rock bit cones, stub shafts, pins, worms, gears and pinions of many types, universal joints, rolls, rocker arms, airplane engine cams, studs, bolts and pins.

With a carbon range above 0.25 per cent this nickel-chromium steel is widely used. Up to 0.35 per cent carbon it is a water-hardening steel, and with a carbon content over 0.35 per cent it is an oil-hardening steel. Typical uses are as connecting rods,

master rods, and straps for airplane engines, compressor crankshafts, spindles, tool joints, chain link stock, engine bolts, superheater bolts, steering knuckles, drive shafts, axles, spring clips, propeller shafts, shovels, picks and so on. In the 0.30 to 0.45 per cent carbon range, the greatest uses include bolts, studs, shafting and gears.

With carbon content greater than 0.50 per cent, this grade is widely used for die blocks, tool holders, gears, pinions, etc.

The 32xx series has an excellent balance of hardening elements which on heat treatment gives a high combination of strength and ductility. These steels are applicable to parts where the service requirements are more severe than can be met with steels of the 31xx series.

While some of the 32xx grade is used with the lower carbon contents (up to 0.25 per cent) for carburized parts, its principal use is in the medium carbon ranges for gears, pinions, and shafting. Because of the alloy content it is not recommended as a water-hardening grade with carbon over 0.30 per cent. Reference to the chart of S. A. E. 3240 steel in the oil-quenched condition shows the wide range of physical values that are available with this steel with variations of the drawing temperature.

S. A. E. RECOMMENDED HEAT TREATMENT (Revised 1935)

S. A. E. No.	Treatment Number	Normalize	Anneal	Quench	Draw
3125 }	I	.....	.....	1500-1550	To desired hardness
3130 }	II	1650-1750	.....	1500-1550	To desired hardness
3135 }	I	.....	.....	1500-1550 oil	To desired hardness
3140 }	II	1650-1750	.....	1500-1550 oil	To desired hardness
X3140	I	.....	.....	1500-1550 oil	To desired hardness
	II	Yes	Yes-M	1500-1550 oil	To desired hardness
3145 }	I	Yes	Yes-M	1500-1550 oil	To desired hardness
3150 }			(for gears draw at 375 to 425)		
3230	I	Yes	Yes-M	1500-1550 oil	To desired hardness
3240	I	Yes	Yes-M	1475-1525 oil	To desired hardness
3245 }	I	Yes	Yes-M	1425-1475 oil	To desired hardness
3250 }	I	Yes	Yes-M	1475-1525 oil	To desired hardness
3325 }	I	Yes	Yes-M	1475-1525 oil	To desired hardness
3335 }	I	Yes	Yes-M	1425-1475 oil	To desired hardness
3340 }	I	Yes	Yes-M	1425-1475 oil	To desired hardness
3435 }	I	Yes	Yes-M	1400-1450 oil	To desired hardness
3450	I	Yes	Yes-M	1400-1450 oil	To desired hardness

M=Machine.

For carburizing or activated bath treatments of S. A. E. 3115, 3120, 3215, 3220, 3312 and 3415, see article on Carburizing Steels, page 95.

PHYSICAL PROPERTIES CHART

S. A. E. 31-15
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.10 /20	.30 /60	.04	.05	.15 /30	1.00 /30	.45 /75	

31-15

			S. ROCK.		C61			C60		C58		C58
156	146	149	S. SHORE		82			80		76		73
19	17	18	I. BRIN.		223			223		212		201
B82	B79	B80	I. SHORE		29			28		27		26
			I. ROCK.		C20			C20		C18		C16

230000

220000

210000

200000

190000

180000

170000

160000

150000

140000

130000

120000

110000

100000

90000

80000

70000

60000

50000

40000

T.S.

Red.

Y.P.

Elong

ANNEALED
1500°F.C.

QUENCH 1425°F. 1425°F. 1425°F. 1425°F.

AS ROLLED

NORM. LED
1700°F.C

DRAW As Quenched 250°F. 350°F. 500°F.

NORMALIZED QUENCHED IN OIL

Tensile Strength

Yield Point

Reduction

Elongation

70%

60%

50%

40%

30%

20%

10%

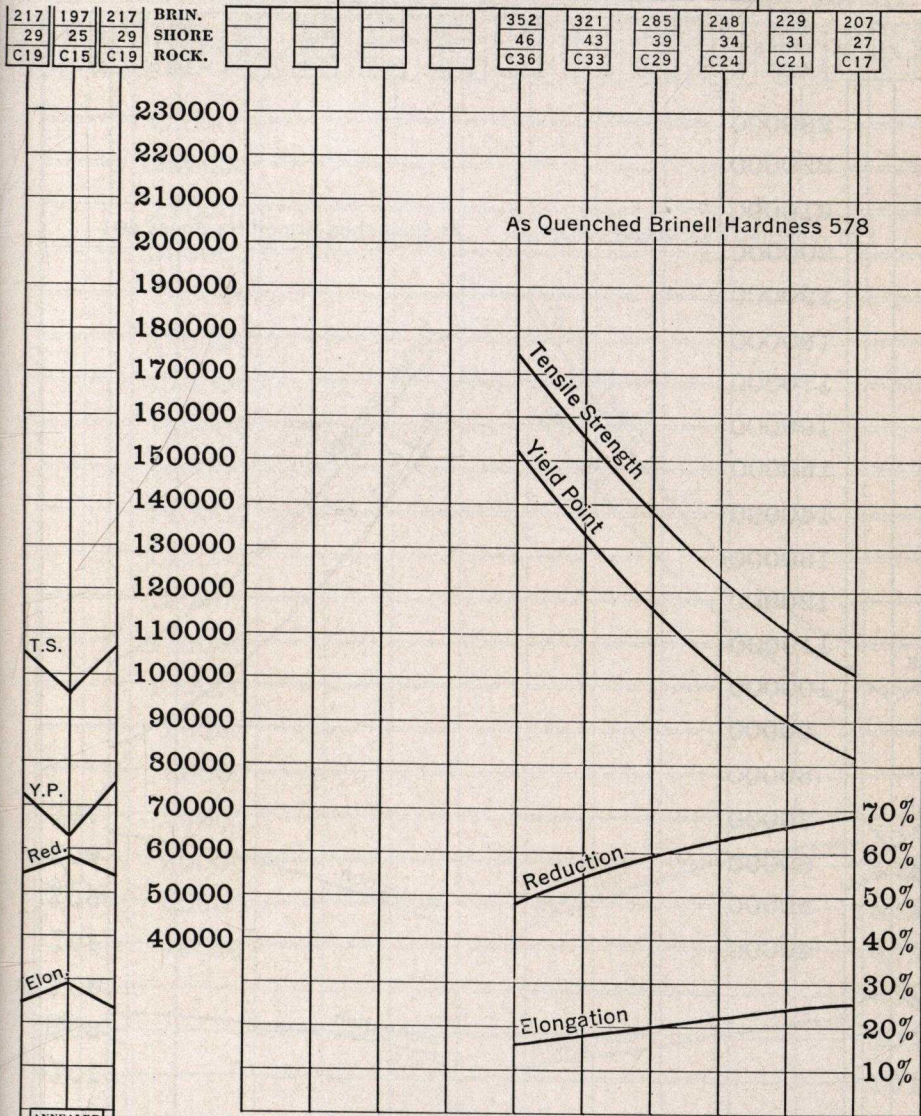
PHYSICAL PROPERTIES CHART

S. A. E. 31-35
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.30/.40	.50/.60	.04	.05	.15/.30	1.00/1.50	.45/.75	

31-35



ANNEALED
1450°F.C.

QUENCH

1525°F. 1525°F. 1525°F. 1525°F. 1525°F. 1525°F.

AS ROLLED

NORMALIZED
1650°F.C.

DRAW

800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.

NORMALIZED

QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

S. A. E. 31-35

(Average Values)

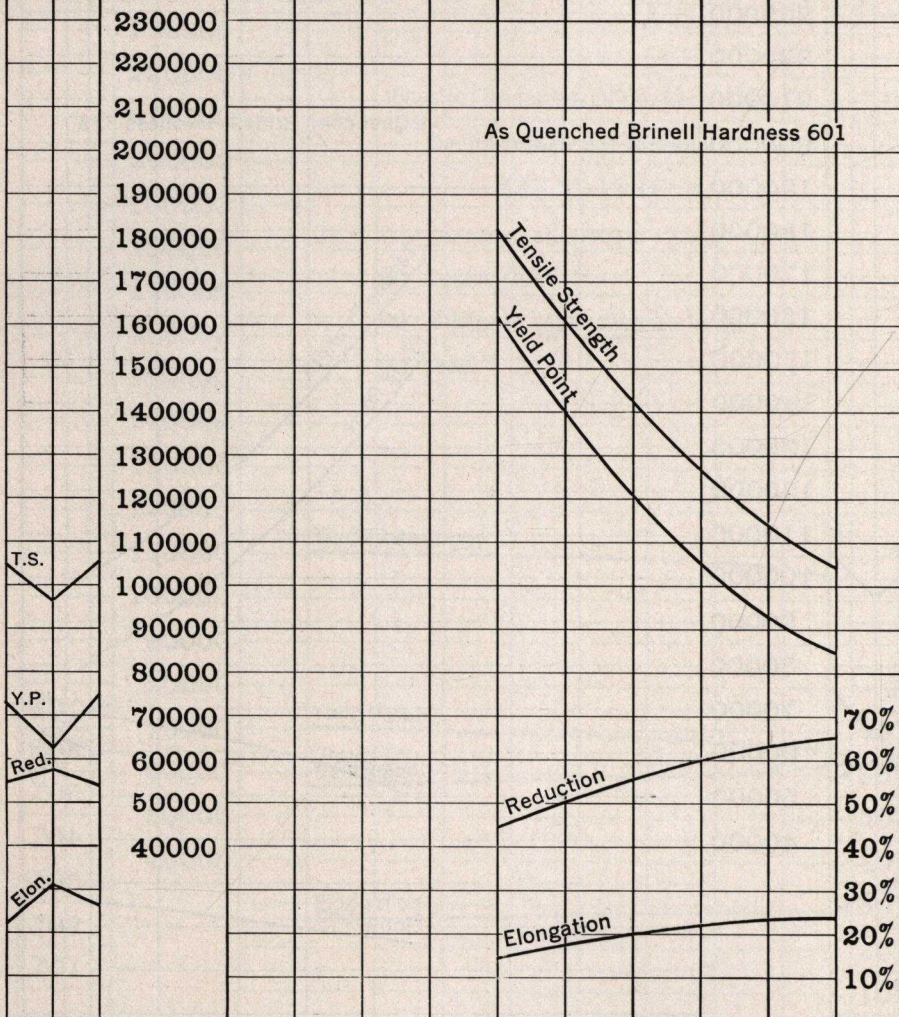
1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.30/40	.50/80	.04	.05	.15/30	1.00/1.50	.45/75	

31-35

217	197	217	BRIN.					375	331	285	262	235	212
29	25	29	SHORE					49	44	39	36	32	28
C19	C15	C19	ROCK.					C38	C34	C29	C26	C22	C18



ANNEALED
1450°F. C

QUENCH

1500°F. 1500°F. 1500°F. 1500°F. 1500°F. 1500°F.

AS ROLLED

NORM'LZD
1650°A.C.

DRAW

800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.

NORMALIZED

QUENCHED IN WATER

PHYSICAL PROPERTIES CHART

S. A. E. 31-45
(Average Values)

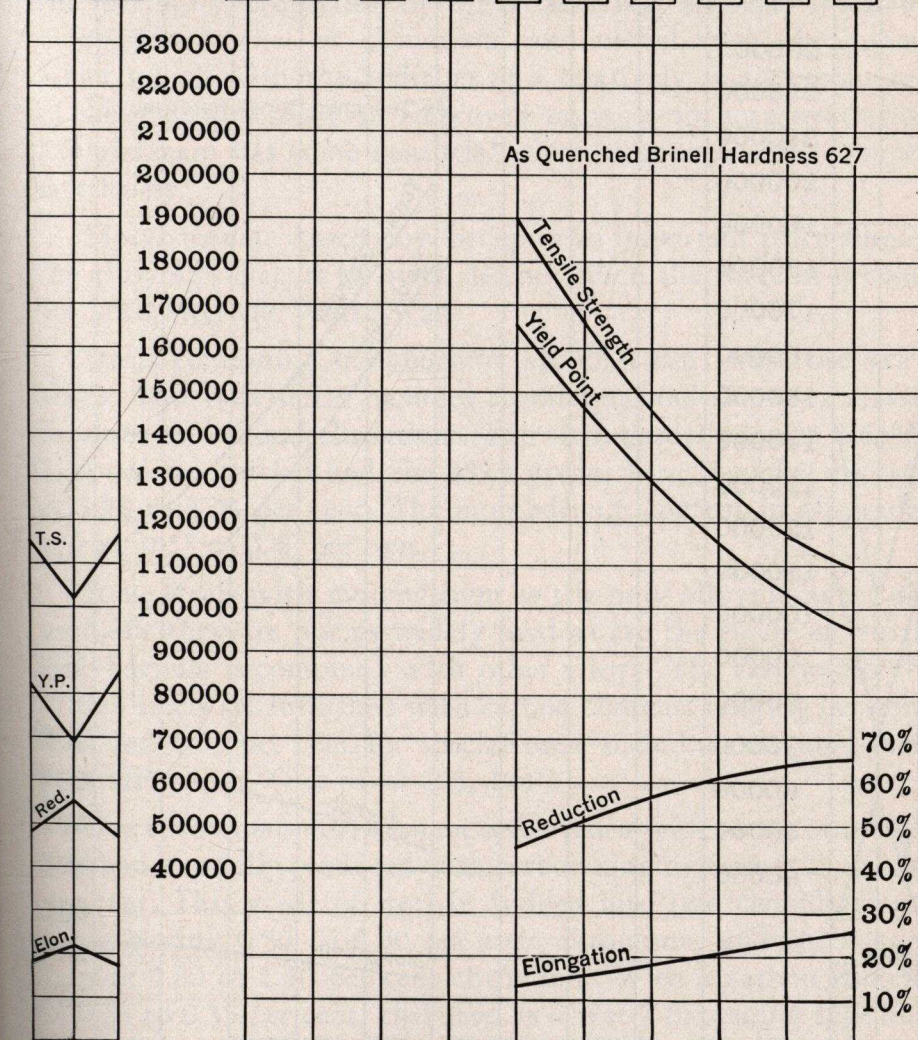
1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.40/50	.60/90	.04	.05	.15/30	1.00/1.50	.45/75	

31-45

235	212	241	BRIN.					388	331	293	269	241	223
32	27	33	SHORE					50	45	40	37	33	30
C22	C18	C23	ROCK.					C39	C34	C30	C27	C23	C20



ANNEALED 1450° F.C. QUENCH 1475° F. 1475° F. 1475° F. 1475° F. 1475° F. 1475° F. 1475° F.

AS ROLLED NORMALED 1625° A.C. DRAW 800° F. 900° F. 1000° F. 1100° F. 1200° F. 1300° F.

NORMALIZED 1625° A.C. QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

S. A. E. 32-40
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.35% 45	.30% 60	.04	.05	.15% 30	1.50% 90	2.00% 1.25	

32-40

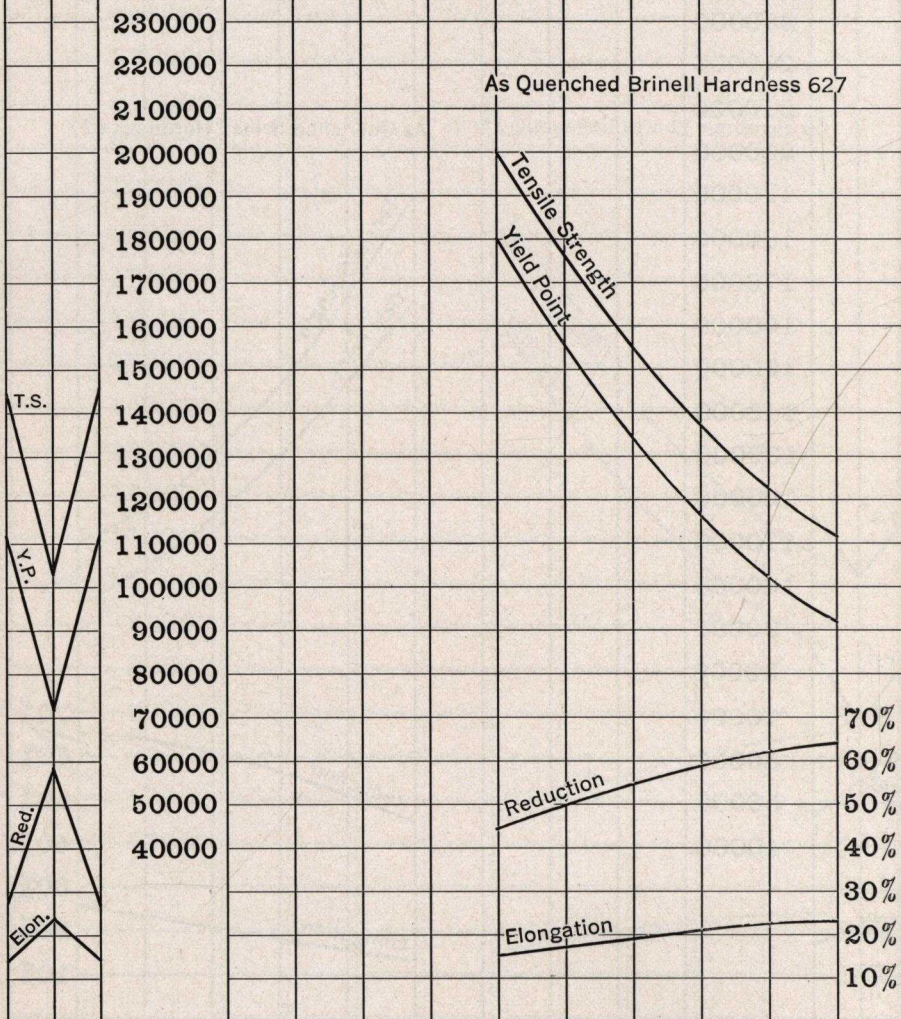
285	197	285
40	25	40
C29	B93	C29

BRIN.
SHORE
ROCK.

401	363
52	47
C41	C37

311	285
42	39
C32	C29

255	229
35	31
C25	C21



AS ROLLED	ANNEALED 1450° F.C.	QUENCH	1500° F.	1500° F.	1500° F.	1500° F.	1500° F.	1500° F.
		DRAW	800° F.	900° F.	1000° F.	1100° F.	1200° F.	1300° F.
	NORM'LED 1625° A.C.	NORMALIZED	1625° A.C.	QUENCHED IN	OIL			

MOLYBDENUM ALLOY STEELS

MOLYBDENUM is used as an alloy in steel because it imparts definite benefits upon subjecting the steel to heat treatment. At present its most general use is mainly to enhance the desirable properties of other alloying elements such as manganese, nickel or chromium, and nickel with chromium, all of which with the addition of a relatively small percentage of molybdenum show an improved response to heat treatment. Molybdenum has some beneficial effect in counteracting temper brittleness.

Molybdenum, which now occupies an important place among the alloying elements for steel, did not reach the stage of general use until after the World War.

Steels containing molybdenum are classified under the 4xxx series. The 41xx series includes chromium, and the 43xx classification, nickel and chromium. The 46xx grades contain 1.65 to 2.00 per cent nickel and the 48xx grades have a nickel content of 3.25 to 3.75 per cent. The molybdenum content in all grades is from 0.15 to 0.40 per cent.

Some steels with molybdenum as the only alloying agent are used but they are not as widely used as are the steels in which molybdenum is combined with other alloys. The carbon-molybdenum steels are furnished with carbon contents ranging between 0.20 and 1.00 per cent for special uses, including elevated temperature service. (See pages 103, 104.)

The chromium-molybdenum series has a wide range of usefulness and is usually produced with carbon ranging from 0.25 to 0.55 per cent. This grade of steel is divided into two classifications, those having 0.50 to 0.80 per cent chromium, and those containing 0.80 to 1.10 per cent chromium. With a carbon content of 0.25 to 0.35 per cent, this steel is a water-hardening type and is used for airplane tubing, bolts, studs, axles, intake valve stems, spindles, shafts, connecting rods and so on.

With carbon content above 0.35 per cent, this steel is an oil-hardening type and is used for such parts as heavy-duty gears, shafts, bolts, studs, piston rods, airplane engine cylinders, etc. This grade is also being used for service at elevated temperatures.

The S. A. E. 46xx series of molybdenum steels, contain 1.65 to 2.00 per cent nickel. With low carbon they are used for carburized parts in which a hard surface and high ductility in the core are demanded. This grade is most widely used for gears of various types in the automotive field, for journals, spline shafts, king pins, pinions, roller bearings, bolts, studs, set screws, collets and so on. With carbon of 0.40 per cent or higher, this type is an excellent steel for oil-hardened parts.

The S. A. E. 48xx series of molybdenum steels is similar to the 46xx except that the nickel content is higher (3.25 to 3.75 per cent).

The combination of nickel and chromium with molybdenum, in the S. A. E. 43xx series, affords an alloy steel rich in hardening elements. This steel provides a combination of very high strength, ductility and resistance to shock. Although it is not produced in large tonnages, it nevertheless fills a very important position where a special-purpose steel is required.

S. A. E. RECOMMENDED HEAT TREATMENT (Revised 1935)

S. A. E. No.	Treatment Number	Normalize	Anneal	Quench	Draw
4130}	I	Yes, or	Yes-M	1550-1650	To desired hardness
X4130)					
4140					
4150					
4340}	I	Yes	Yes-M	1500-1600 oil	To desired hardness
4345)					
4640	I	Yes	Yes-M	1450-1500 oil*	350-450
	II	Yes	Yes-M	1450-1550 oil	To desired hardness

*For gears—heat in cyanide or activated bath.

M = Machine.

For carburizing treatments of S. A. E. 4615, 4620, 4815 and 4820, see article on Carburizing Steels, page 95.

PHYSICAL PROPERTIES CHART

S. A. E. 41-30
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	Mo.
.25/.35	.50/.80	.04	.05	.15/.30		.50/.80	.15/.25

41-30

229	179	207	BRIN.					363	352	321	285	255	241
32	21	27	SHORE					49	47	44	40	36	34
C21	B88	C17	ROCK.					C37	C36	C33	C29	C25	C23

230000
220000
210000
200000
190000
180000
170000
160000
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000

As Quenched Brinell Hardness 514

Tensile Strength
Yield Point

Reduction

Elongation

70%
60%
50%
40%
30%
20%
10%

T.S.

Y.P.

Red.

Elong.

ANNEALED
1450°F.C.

QUENCH 1600°F. 1600°F. 1600°F. 1600°F. 1600°F. 1600°F.

DRAW 800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.

AS ROLLED NORM'LZD
1650°A.C.

NORMALIZED QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

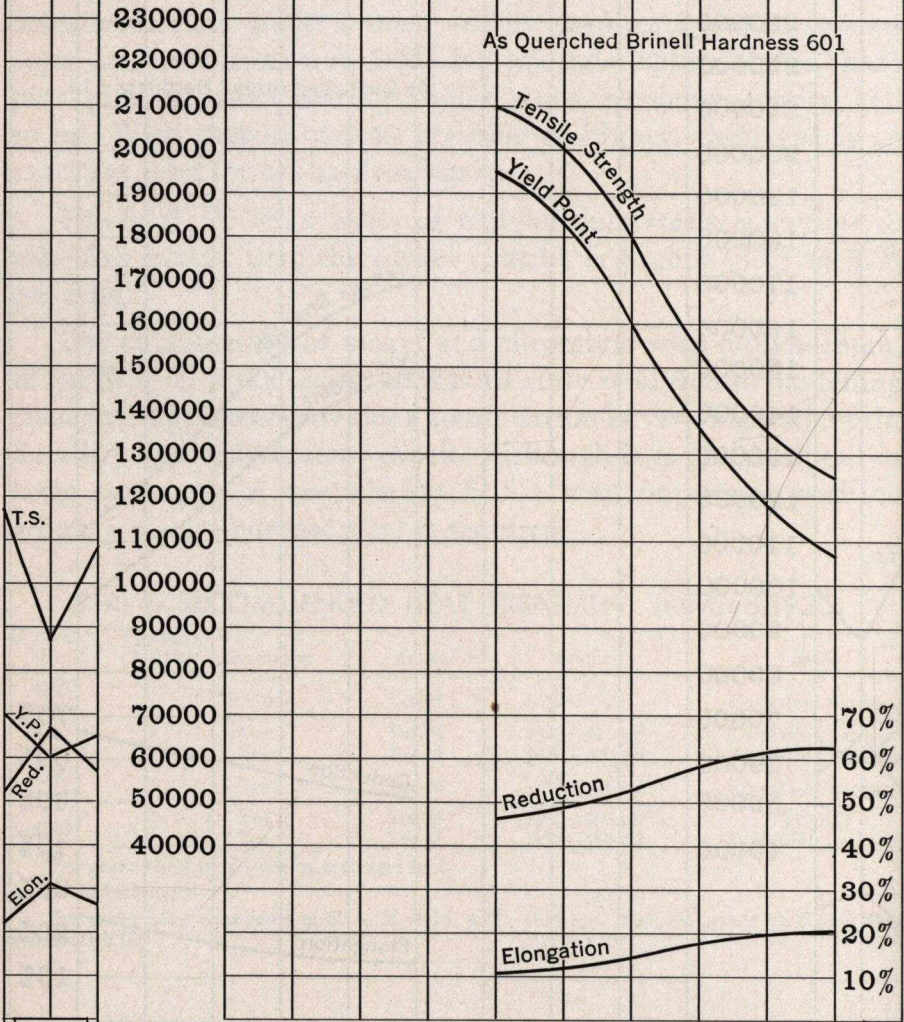
S. A. E. 41-30
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	Mo.
.25 35	.50 80	.04	.05	.15 30		.50 80	.15 25

41-30

229	179	207	BRIN.					429	401	363	302	277	248
32	21	27	SHORE					56	52	47	40	38	33
C21	B88	C17	ROCK.					C44	C41	C37	C31	C28	C24



ANNEALED 1450°F.C. QUENCH _____ 1550°F. 1550°F. 1550°F. 1550°F. 1550°F. 1550°F.
AS ROLLED NORM'LED 1650°F.C. DRAW _____ 800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.
NORMALIZED _____ QUENCHED IN WATER

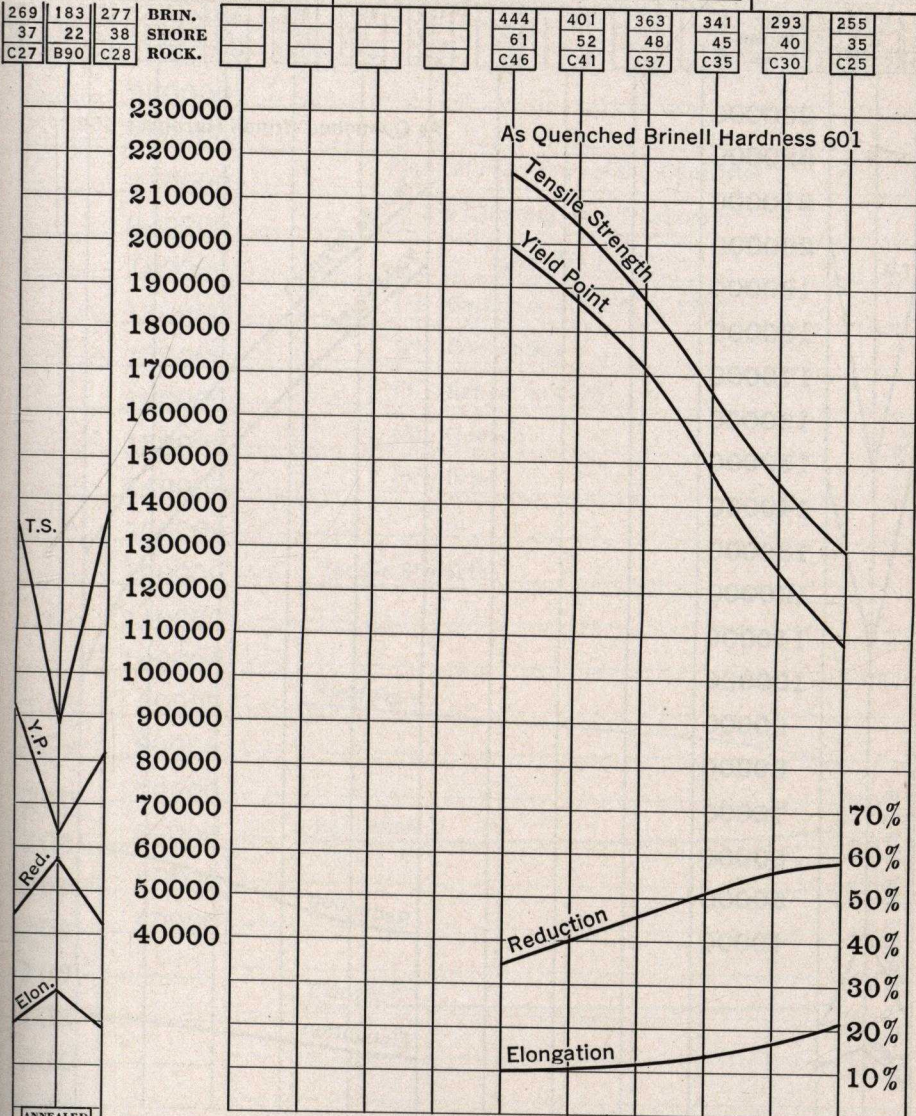
PHYSICAL PROPERTIES CHART

S. A. E. 41-40
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	Mo.
.35 45	.60 90	.04	.05	.15 30		.80 1.10	.15 25

41-40



ANNEALED 1450°F.C. QUENCH 1575°F. 1575°F. 1575°F. 1575°F. 1575°F. 1575°F.
AS ROLLED DRAW 800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.
NORMALIZED 1650°C. QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

S. A. E. 43-40
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

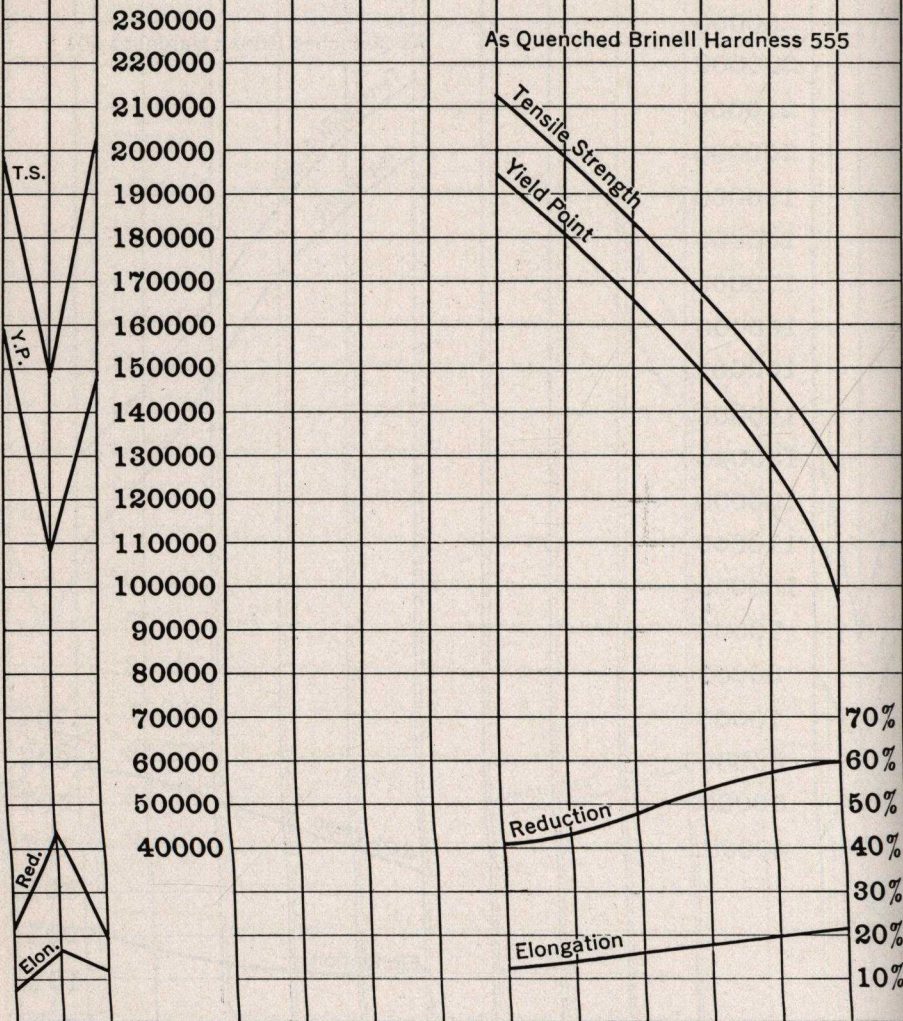
C.	Mn.	P.	S.	Si.	Ni.	Cr.	Mo.
.35/45	.50/60	.040	.050	.15/30	1.50/2.00	.50/80	.30/40

43-40

401	302	415
52	40	53
C41	C31	C42

BRIN.
SHORE
ROCK.

429	401	375	331	302	269
54	52	48	43	40	36
C43	C41	C38	C34	C31	C27



PHYSICAL PROPERTIES CHART

S. A. E. 46-15
(Average Values)

46-15

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

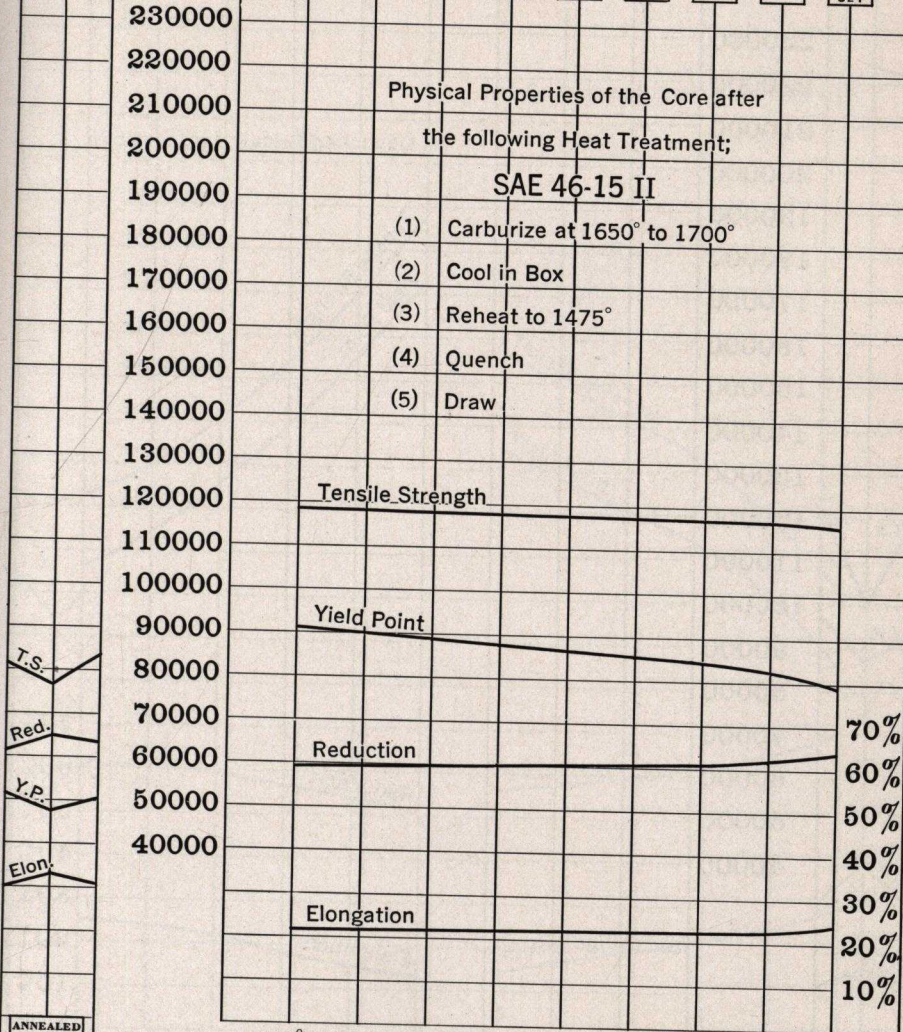
C.	Mn.	P.	S.	Si.	Ni.	Cr.	Mo.
.10/ /20	.40/ /70	.04	.05	.15/ /30	1.65/ /2.00	—	.20/ /30

S. ROCK.	S. SHORE	I. BRIN.	I. SHORE	I. ROCK.	C64	84	C62	82	C60	80	C58	77
167	149	170	20	20	248	248	248	242	242	229	229	229
B85	B80	B86			C24	C24	C24	C23	C23	C21	C21	C21

Physical Properties of the Core after
the following Heat Treatment;

SAE 46-15 II

- (1) Carburize at 1650° to 1700°
- (2) Cool in Box
- (3) Reheat to 1475°
- (4) Quench
- (5) Draw



ANNEALED
1600° F.C.

QUENCH 1475°F. 1475°F. 1475°F. 1475°F.
NORM'L'D DRAW As Quenched 250°F. 350°F. 500°F.
NORMALIZED QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

S. A. E. 46-40
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

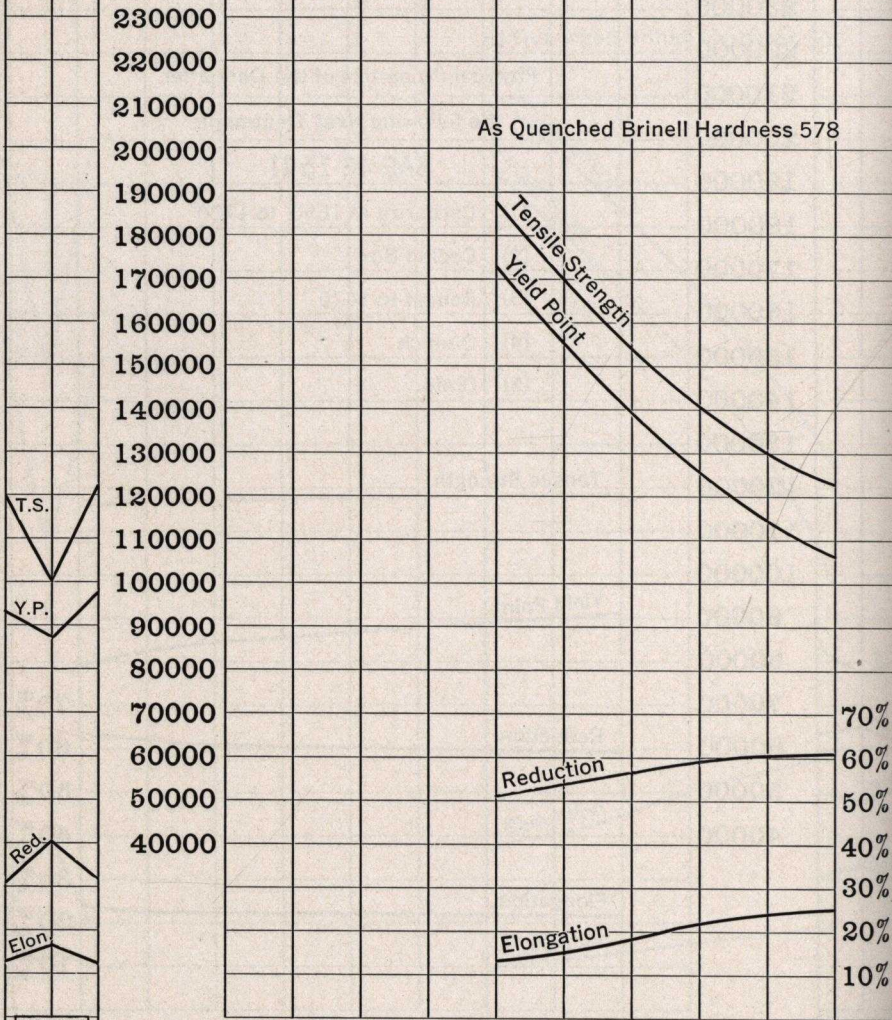
C.	Mn.	P.	S.	Si.	Ni.	Cr.	Mo.
.35 / .45	.50 / .60	.04	.05	.15 / .30	1.65 / 2.00		.20 / .30

46-40

241	201	248
32	27	33
C23	C16	C24

BRIN.
SHORE
ROCK.

388	363	321	293	269	241
49	47	42	39	36	32
C39	C37	C33	C30	C27	C23



ANNEALED 1450° F. C.

QUENCH _____

AS ROLLED _____

NORMALIZED 1600° A. C.

DRAW _____

1500° F. 1500° F. 1500° F. 1500° F. 1500° F. 1500° F.

800° F. 900° F. 1000° F. 1100° F. 1200° F. 1300° F.

NORMALIZED 1600° A. C. QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

.20 CARBON — MANGANESE — MOLYBDENUM STEEL

(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

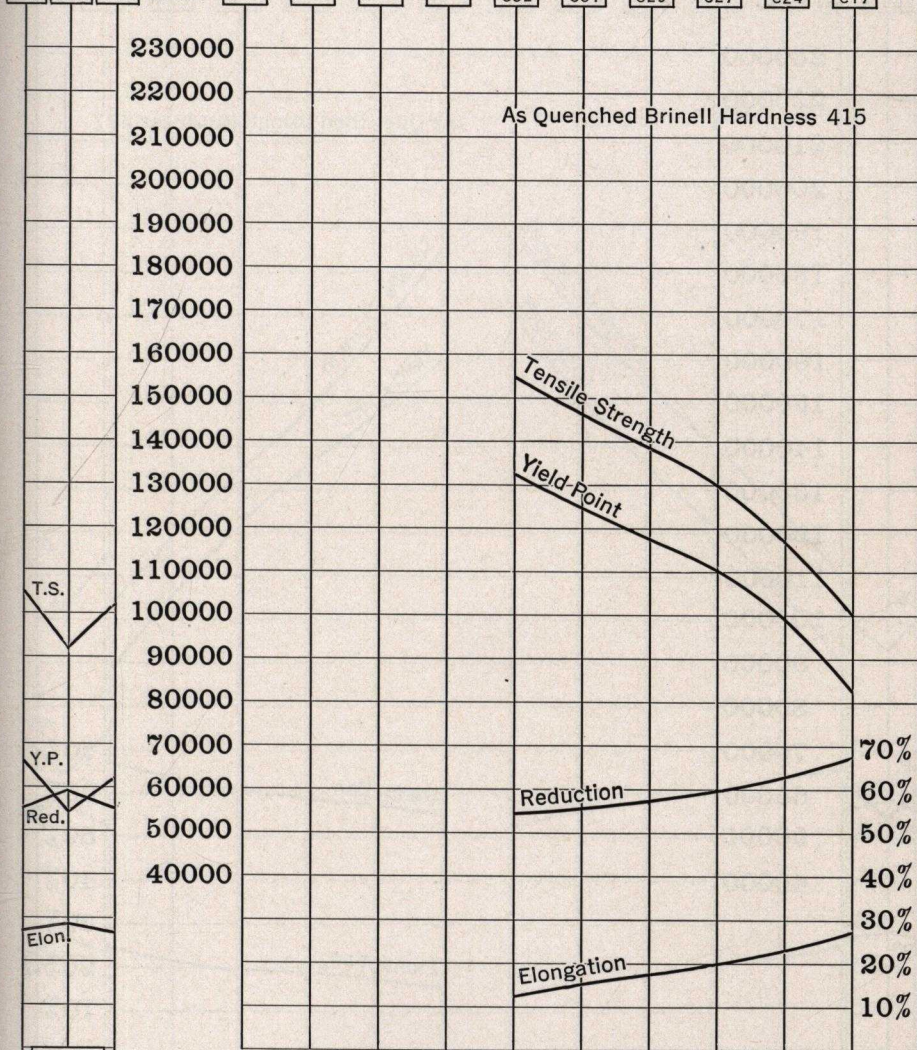
C.	Mn.	P.	S.	Si.	Ni.	Cr.	Mo.
.18/.23	1.15/1.45	.05	.05	.35/40			.25/.35

.20 CARBON
MANG. MOLY.
STEEL

217	179	217
28	22	28
C19	B87	C19

BRIN.
SHORE
ROCK.

311	302	285	269	248	207
41	40	38	36	33	27
C32	C31	C29	C27	C24	C17



PHYSICAL PROPERTIES CHART

.20 CARBON—MANGANESE—MOLYBDENUM STEEL

(Average Values)

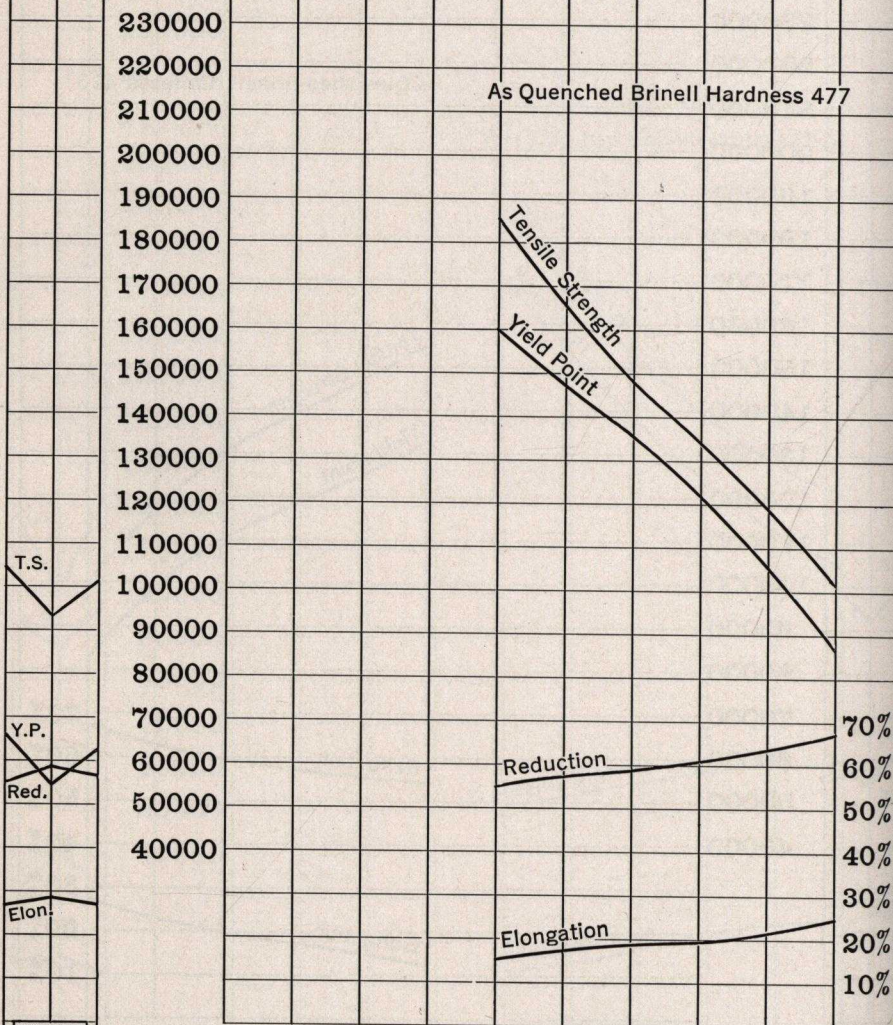
1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	Mo.
.18/ 23	1.15/ 1.45	.05	.05	.35/ 40			.25/ 35

.20 CARBON
MANG.-MOLY.
STEEL

217	179	217	BRIN.					375	341	302	277	248	207
28	22	28	SHORE					48	44	40	37	34	27
C19	B87	C19	ROCK.					C38	C35	C31	C28	C24	C17



AS ROLLED

NORM'LZD
1700°F. C.

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

241	197	241
32	26	32
C23	C15	C23

C.	Mn.	P.	S.	Si.	Ni.	Cr.	Mo.
.28 / .38	1.15 / 1.45	.05	.05				.25 / .35

**.33 CARBON
MANG.-MOLY.
STEEL**

388	352	321	293	255	229
49	45	42	39	34	30
C39	C36	C33	C30	C25	C21



CHROMIUM STEELS

CHROMIUM as an alloy in steel is essentially a hardener and does not materially improve ductility. Steels with chromium as the only alloying element contain a lower carbon content as compared with the chromium-free steels, resulting in a combination of high strength with satisfactory ductility.

The chromium steels are in the S. A. E. 5xxx Series. In the 51xx type the lower carbon carburizing grade contains 0.60 to 0.90 per cent chromium. Oil-hardening steels which have carbon in ranges of 0.35 to 0.45 and 0.45 to 0.55 per cent have 0.80 to 1.10 per cent chromium. These steels are used for springs, gears, shear blades, studs, bolts and the usual industrial uses for which oil-hardening grades are suited.

The 52100 grade is a special-purpose steel containing 0.95 to 1.10 per cent carbon and 1.20 to 1.50 per cent chromium. It is used principally for balls, ball races, rollers and roller bearings.

Chromium steels other than those listed as S. A. E. often find definite and extensive use in industry.

A number of types of steel contain 0.25 to 0.60 per cent chromium, and these steels usually have 0.45 to 1.20 per cent carbon in the accepted ranges and are oil hardening. Uses for these steels include magnets, axes, mine bits, grinding balls, springs and wood-cutting tools.

Steel containing chromium is used for intake valves in internal combustion engines. These steels have from 1.85 to 2.70 per cent chromium, in varying ranges, and contain approximately 4.00 per cent silicon and around 0.40 per cent carbon.

S. A. E. RECOMMENDED HEAT TREATMENT (Revised 1935)

S.A.E. No.	Treatment Number	Normalize	Anneal	Quench	Draw
5140	I	Yes	Yes-M	1500-1600 oil	To desired hardness
	II	Yes	Yes-M	1475-1525 oil*	Gears (375-450)
5150	I	Yes	Yes-M	1450-1550 oil	To desired hardness
	II	Yes	Yes-M	1475-1525 oil	Gears (375-425)
52100	I	....	1350-1450**	1425-1475 H ₂ O	To desired hardness
				or 1500-1600 oil	To desired hardness

*In cyanide or activated bath for gears.

**Cool slowly 7-35 hours for uniformly distributed spheroidized structure.

M=Machine.

For carburizing or activated bath treatments of S. A. E. 5120, see article on Carburizing Steels, page 95.

PHYSICAL PROPERTIES CHART

S. A. E. 51-40

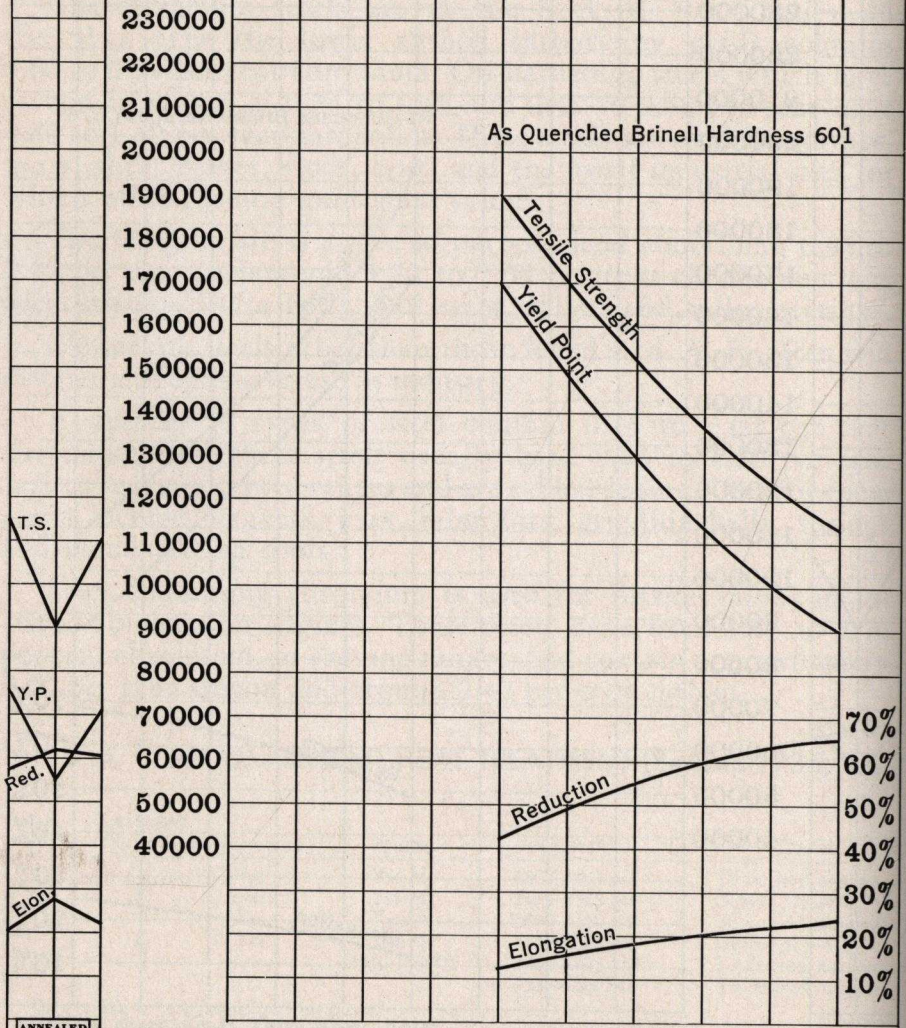
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.35/.45	.60/.90	.04	.05	.15/.30		.80/1.10	

51-40

223	183	212	BRIN.					375	352	302	269	241	229
29	22	27	SHORE					49	47	41	37	33	31
C20	B90	C18	ROCK.					C38	C36	C31	C27	C23	C21



QUENCH _____ 1550°F. 1550°F. 1550°F. 1550°F. 1550°F. 1550°F.
DRAW _____ 800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.
NORMALIZED 1625 A.C. QUENCHED IN OIL

PHYSICAL PROPERTIES CHART

S. A. E. 51-50
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.45/ /55	.60/ /90	.04	.05	.15/ /30		.80/ /110	

51-50

277	201	285	BRIN.					461	401	352	302	269	235
37	27	38	SHORE					63	52	45	40	36	31
C28	C16	C29	ROCK.					C48	C41	C36	C31	C27	C22

230000
220000
210000
200000
190000
180000
170000
160000
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000

As Quenched Brinell Hardness 627

Tensile Strength
Yield Point

Reduction

Elongation

70%
60%
50%
40%
30%
20%
10%

T.S.

Y.P.

Red.

Elong.

ANNEALED
1450°F.C.

QUENCH _____ 1525°F. 1525°F. 1525°F. 1525°F. 1525°F. 1525°F.
DRAW _____ 800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.

NORMALIZED 1625°A.C.

QUENCHED IN OIL

AS ROLLED

NORM'LZD
1625°A.C.

VANADIUM ALLOY STEELS

VANADIUM as an alloy in steel has the characteristic property of developing a finer-grained structure. The benefits of vanadium additions to steel are not entirely reflected by the vanadium content of the steel by analysis, since vanadium is a deoxidizer and acts in that capacity when added to the molten metal. The effect of vanadium on the physical properties of a heat-treated steel is to promote ductility and accentuate the benefits of other alloying elements such as manganese and chromium.

The chromium-vanadium steels, which are in the 61xx series, contain from 0.80 to 1.10 per cent chromium and a minimum of 0.15 per cent vanadium. These steels are made with carbon contents from 0.10 to 1.05 per cent with the usual ranges.

In the lower carbon ranges, up to 0.25 per cent carbon, this type of steel is generally used for carburized parts such as pneumatic tool parts, wrenches, roller bearing cones, pistons, and other parts in which carburized alloy steels are used and where stresses are high.

In the 0.35 to 0.45 per cent carbon range, the chromium-vanadium steels are used as oil-hardened heavy-duty axles, shafts, driving parts, gears, pinions and similar parts.

This grade is used to some extent in the chemical industry because of its resistance to rapid deterioration when exposed to hydrogen gas in service.

In the 0.45 to 0.55 per cent carbon range, a considerable tonnage of flat spring steel has been produced. This type steel is also used for coil springs, mostly in the smaller sizes. In the automotive field a flat leaf of chromium-vanadium steel is sometimes used in conjunction with carbon spring steel (S. A. E. 1095) in the spring assembly.

In the higher carbon ranges this grade is only used for special purpose or heavy-duty work such as rams, liners, anti-friction bearings, and machine tool parts.

Steels with vanadium as the only alloying element contain approximately 0.15 to 0.25 per cent vanadium. They have but little use in the low-carbon ranges. In the 0.45 to 0.55 per cent carbon range, with manganese slightly higher than normal, these steels are widely used in normalized and drawn forgings for locomotives. In the higher carbon ranges, 0.85 to 1.00 per cent, they are used for beater bars, digging bars, wood-and stone-cutting tools and for other services of this type.

S. A. E. RECOMMENDED HEAT TREATMENT (Revised 1935)

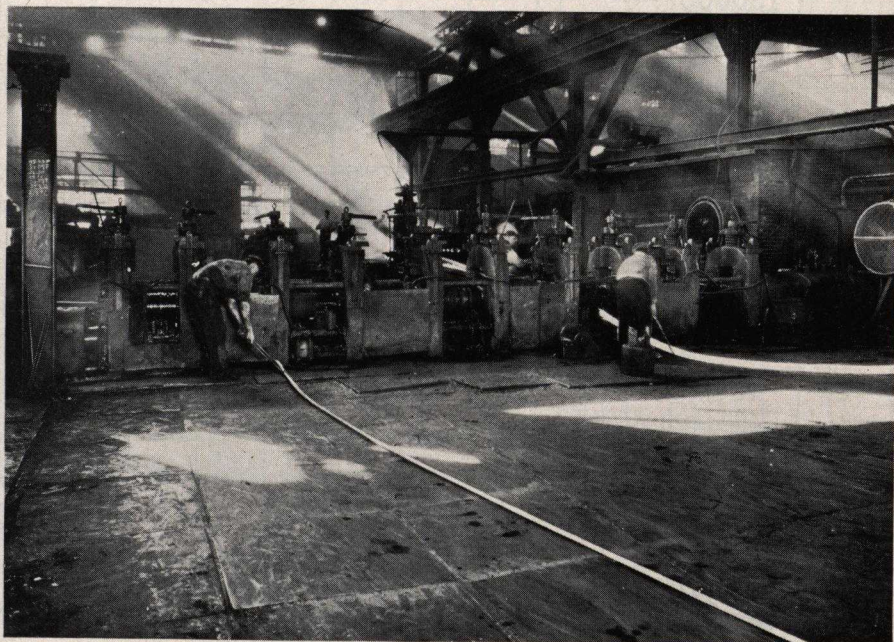
S. A. E. No.	Treatment Number	Normalize	Anneal	Quench	Draw
6125 }	{ I	.....	.....	1575-1625	To desired hardness
6130 }		1650-1750	.....	1575-1625	To desired hardness
6135 }	I	Yes	Yes-M	1550-1650 oil	To desired hardness
6140 }					
6145 }	I	Yes	Yes-M	1525-1625 oil	To desired hardness*
6150 }					
6195	I	.....	1330-1380**	1425-1475 H ₂ O or 1500-1600 oil	To desired hardness To desired hardness

*388 to 444 Brinell hardness for leaf springs.

**Cool slowly 7-35 hours for uniformly distributed spheroidized structure.

M = Machine.

For carburizing or activated bath treatments of S. A. E. 6115 and 6120, see article on Carburizing Steels, page 95.



Small bar mill

PHYSICAL PROPERTIES CHART

S. A. E. 61-40
(Average Values)

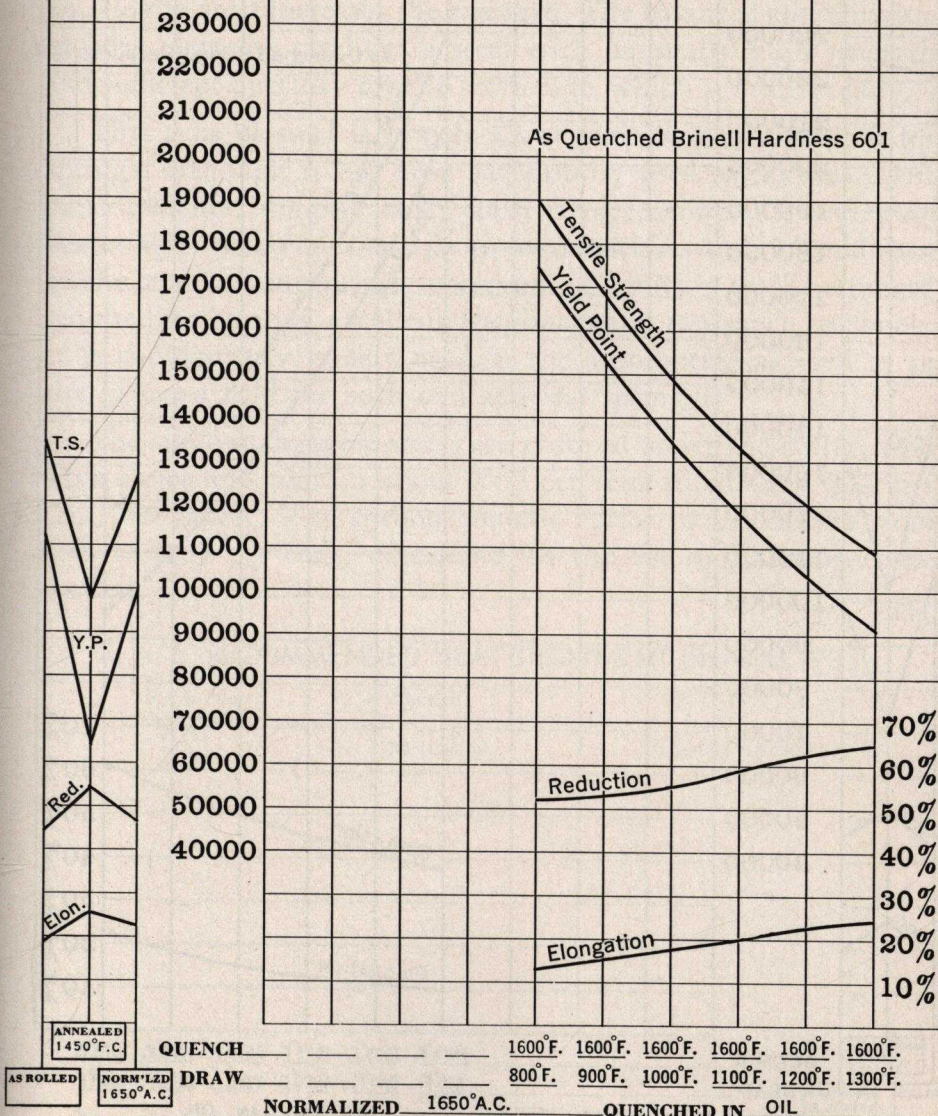
1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED

C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.35/.45	.60/.90	.04	.045	.15/.30		.80/.110	.15 (.18)

61-40

277	201	262	BRIN.					388	341	311	269	241	223
37	27	35	SHORE					50	45	41	36	32	30
C28	C16	C26	ROCK.					C39	C35	C32	C27	C23	C20



PHYSICAL PROPERTIES CHART

S. A. E. 61-50
(Average Values)

1" Dia. SIZE TREATED
.505" x 2" SIZE TESTED

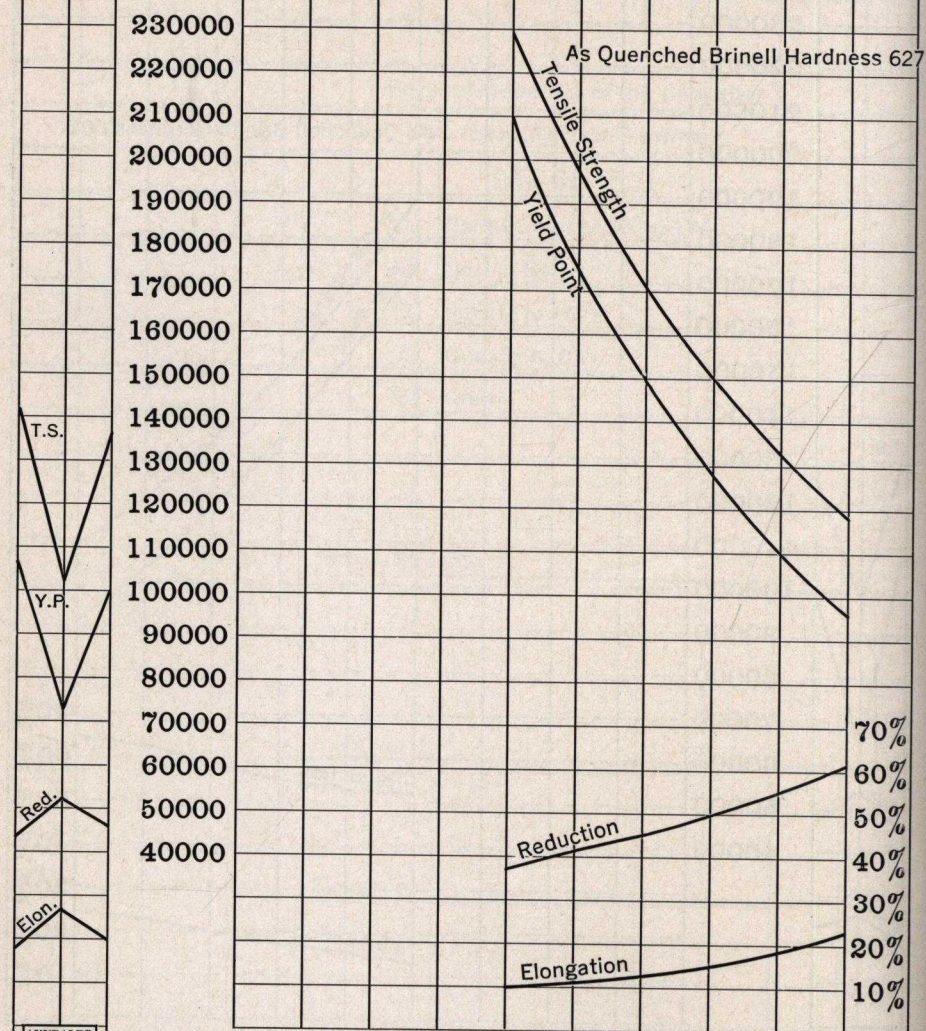
C.	Mn.	P.	S.	Si.	Ni.	Cr.	V.
.45/55	.60/90	.04	.045	.15/30		.80/1.10	15(18)

61-50

285	201	277
39	27	38
C29	C16	C28

BRIN.
SHORE
ROCK.

				461	401	341	302	262	235
				63	53	46	41	36	32
				C48	C42	C36	C32	C27	C23



ANNEALED 1450°F.C.	QUENCH	AS ROLLED	NORM'LZD 1650°F.C.
	DRAW		

1575°F. 1575°F. 1575°F. 1575°F. 1575°F. 1575°F.
800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.
NORMALIZED 1650°F.C. QUENCHED IN OIL

SILICO-MANGANESE STEELS

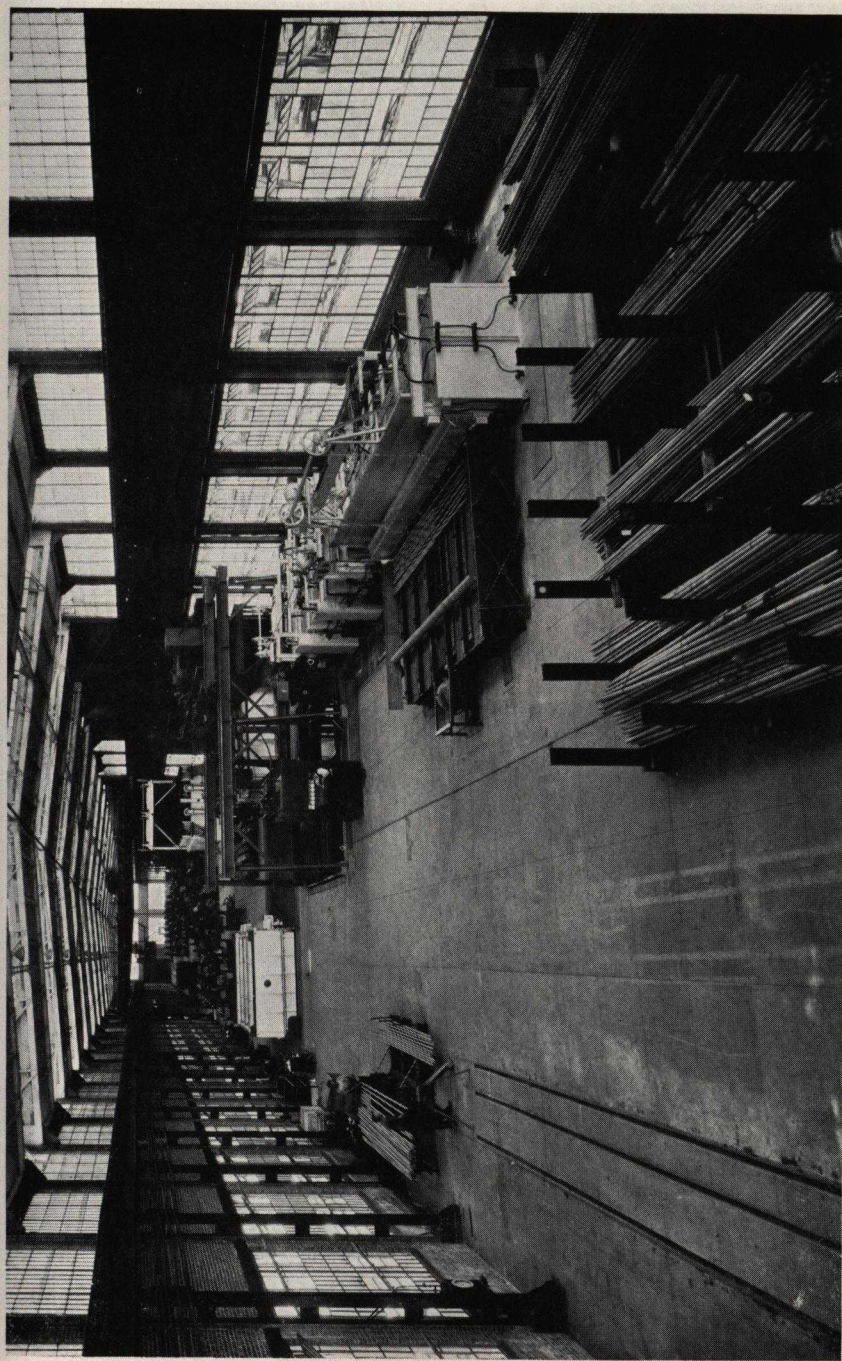
SILICON is recognized as being a powerful deoxidizing agent and manganese to a lesser degree behaves in the same manner. As has been previously pointed out, manganese exerts beneficial effects on the physical properties of heat-treated steel. Silicon as an alloy in steel increases the strength. The balanced combination of both elements produces a steel with unusually high strength and sufficient ductility for the services to which it is adapted.

This type of steel is largely a one-purpose grade, mainly for springs, although it has been successfully used for chisels, drift pins, punches, digging bars, shear blades, mine bits and pulp beater bars. It responds readily to oil quenching and, when drawn to the correct temperature, possesses, in addition to the strength required by springs, excellent toughness and resistance to shock. It is consequently widely used in the automotive as well as in the railroad field for both coil and leaf springs.

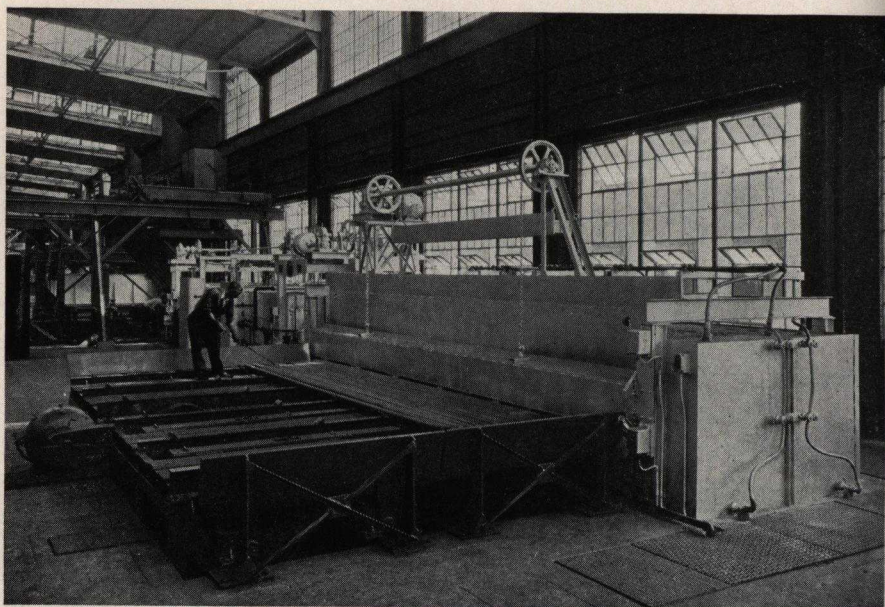
The silico-manganese steels are grouped under the designation 92xx series and contain about 2.00 per cent silicon and 0.80 per cent manganese. The carbon content varies in increments from 0.48 to 0.67 per cent, depending on the use and section to be treated.

S. A. E. RECOMMENDED HEAT TREATMENT (Revised 1935)

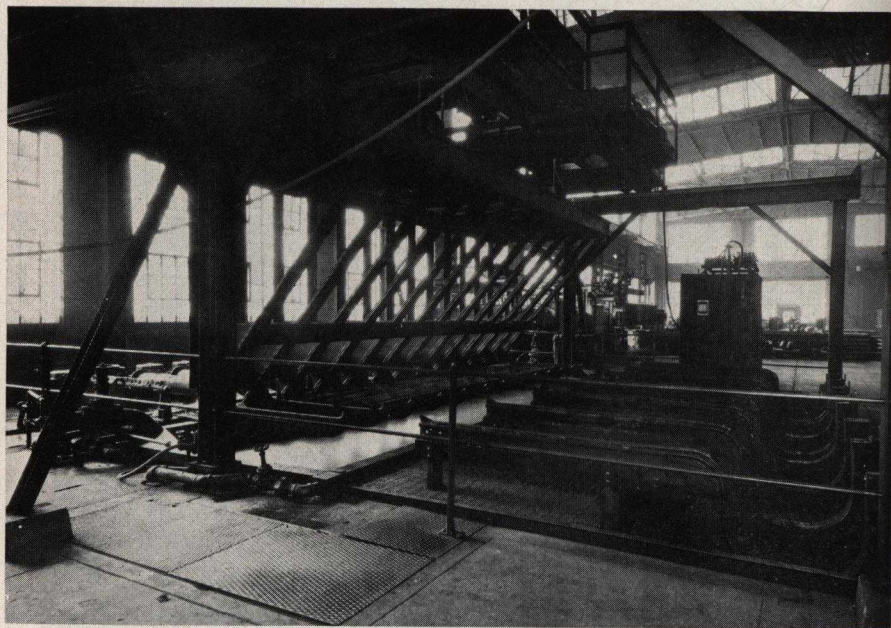
S.A.E. No.	Quench	Draw
9255 } 9260 }	1550-1650 oil	To desired hardness



General view of the electric furnace heat-treating department for bars



Charging mechanism and preheat chamber of roller hearth continuous furnace for heating bars for quenching in electric furnace heat-treating department



Discharge end showing bars lifted from roller line, in the cradle above quenching tank. Electric heating furnace immediately adjacent at back of cradle

PART 2

STEELS FOR SPECIFIC USES

CARBURIZING STEELS

NITRIDING STEELS

STEELS FOR ELEVATED TEMPERATURES

BEARING STEELS

MAGNET STEELS

ALLOY GEAR STEELS

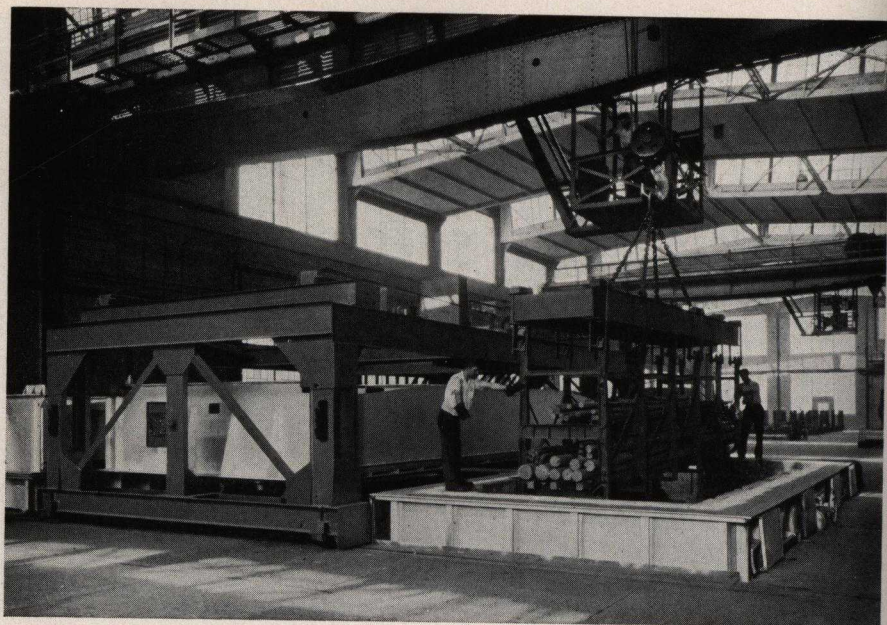
TOOLS AND MACHINE PARTS

STEELS FOR RAILROAD SERVICE

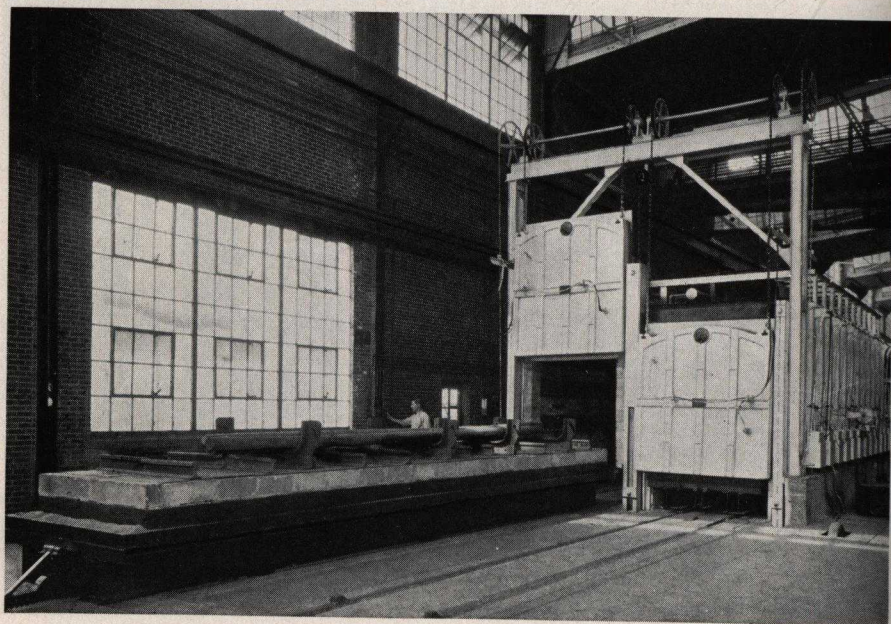
SPRING STEELS

AIRPLANE QUALITY STEELS

STEELS FOR THE OIL INDUSTRY



The two pit-furnaces in the electric furnace heat-treating department.
One being loaded



The two car-type heat-treating furnaces in the electric furnace
heat-treating department. One being loaded

CARBURIZING STEELS

A CARBURIZING steel is a low-carbon steel, either simple or alloy grade, which in service must, after carburizing and proper treatment, possess a tough shock-resisting core and a hard case to resist wear.

To obtain these results, the user has a choice not only of a number of different grades of steel but also of carburizing operations. In each case the service requirements must be balanced against the cost and treatment of the steel.

In general, it can be said of carburizing steels that the cores of carbon steels possess the least ductility, and that, of the alloy steels, the S. A. E. 2515 has the highest combination of core strength and ductility. The fine-grained (A.S.T.M. E19-33*) alloy steels, such as S. A. E. 3115 and S. A. E. 4615, have become more widely used during the last few years, because they have the property of producing good refinement and minimum distortion with a single quench.

For light parts or where extremely tough cores are required, the carbon content should preferably be 0.18 per cent maximum. For heavy parts with strong cores carbon content should be from 0.15 to 0.25 per cent.

When the double quenching method is used, the first temperature is higher to refine the core and to dissolve the free carbides in the case, and the second temperature is lower to refine the high-carbon case and at the same time to temper the low-carbon core.

When one quench is used, it must be at the higher temperature if refinement of the core is the purpose of the treatment, as shown in the recommended heat treatment tables. A fine-grained (A.S.T.M. E19-33*) steel will be most satisfactory for this purpose, giving a minimum coarsening of the case.

Carburizing materials are either solids, liquids, or gases; the solid materials being most generally used. The rate of carbon penetration depends on the carburizing agent used, the length of

*See pages 123-134

time, and the degree of temperature to which the part is exposed during the carburizing operation.

Service requirements determine the final depth of the hardened case. For most parts the carbon penetration must be sufficiently deep to allow for the removal of 0.010 to 0.015 inch of material by subsequent grinding. If the part is of such a shape that unusual warpage is likely to occur, this allowance must be increased.

The case must be sufficiently deep to provide uniform hardening without soft spots and to withstand the required amount of wear in service. Unnecessarily deep cases increase cost and susceptibility to breakage by severe shock.

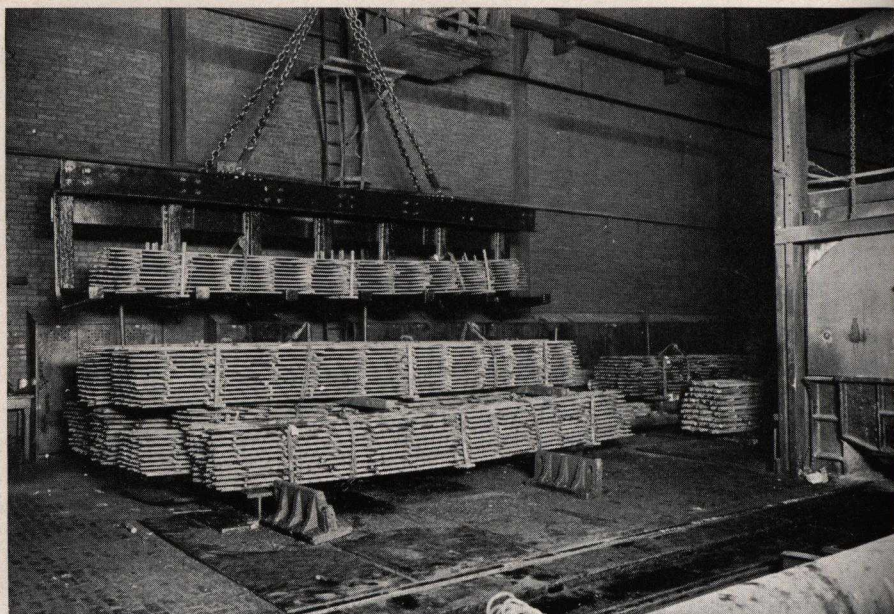
S. A. E. RECOMMENDED HEAT TREATMENT (Revised 1935)

S.A.E. No.	Treat. No.	Normal-ize	Carburize Deg. F.	Cool	Reheat Deg. F.	Cool	Reheat Deg. F.	Cool	Draw Deg. F.
1010 1015	I	.....	1650-1700	quench	.....	.....	.....	.....	250-325
	II	.....	1650-1700	quench	1400-1450	H ₂ O	.....	.....	250-325
	III	.....	1650-1700	in box	1400-1450	H ₂ O	.....	.....	250-325
	IV	.....	1650-1700	in box	1650-1700	oil or H ₂ O	1400-1450	H ₂ O	250-325
	V	.....	1500-1650*	oil or H ₂ O	.....	.....	.....	.....	optional
X1015 1020 X1020	I	.....	1650-1700	quench	.....	.....	.....	.....	250-325
	II	.....	1650-1700	quench	1400-1450	oil or H ₂ O	.....	.....	250-325
	III	.....	1650-1700	in box	1400-1450	oil or H ₂ O	.....	.....	250-325
	IV	.....	1650-1700	in box	1650-1700	oil or H ₂ O	1400-1450	quench	250-325
	V	.....	1500-1650*	oil or H ₂ O	.....	.....	.....	.....	optional
1025 X1025 1030 1112	I	.....	1500-1650*	oil or H ₂ O	.....	.....	.....	.....	optional
1115 1120 X1314 X1315	I	.....	1650-1700	quench	.....	.....	.....	.....	250-325
	II	.....	1650-1700	quench	1400-1450	quench	.....	.....	250-325
	III	.....	1650-1700	in box	1400-1450	quench	.....	.....	250-325
	IV	.....	1650-1700	in box	1650-1700	quench	1400-1450	quench	250-325
	V	.....	1500-1650*	oil or H ₂ O	.....	.....	.....	.....	optional
2015	I	.....	1650-1700	quench	.....	.....	.....	.....	250-300
	II	.....	1650-1700	quench	1400-1450	quench	.....	.....	250-300
	III	.....	1650-1700	in box	1400-1450	quench	.....	.....	250-300
	IV	.....	1650-1700	in box	1650-1700	quench	1400-1450	quench	250-300
	V	.....	1500-1650*	quench	.....	.....	.....	.....	optional
2115	I	.....	1650-1700	quench	.....	.....	.....	.....	250-300
	II	.....	1650-1700	quench	1375-1425	oil	.....	.....	250-300
	III	.....	1650-1700	in box	1375-1425	oil	.....	.....	250-300
	IV	.....	1650-1700	in box	1650-1700	oil	1375-1425	oil	250-300
	V	.....	1650-1700*	oil	.....	.....	.....	.....	optional

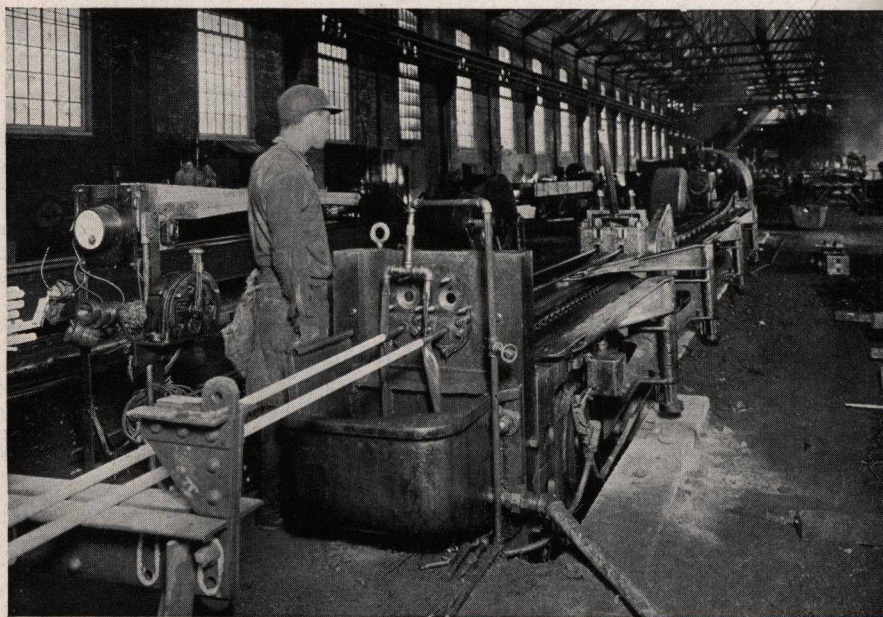
S. A. E. Recommended Heat Treatment (Continued)

S. A. E. No.	Treat. No.	Normalize	Carburize Deg. F.	Cool	Reheat Deg. F.	Cool	Reheat Deg. F.	Cool	Draw Deg. F.	
2315 2320	I	Yes	1650-1700	quench	1350-1400†	oil	.....	.....	230-300	
		Yes	1650-1700	quench	1450-1500‡	oil	.....	.....	250-300	
		Yes	1650-1700	in box	1350-1400†	oil	.....	.....	250-300	
		Yes	1650-1700	in box	1450-1500‡	oil	.....	.....	250-300	
		Yes	1650-1700	in box	1500-1550	oil	1350-1400	oil	250-300	
2515	V	.....	1450-1650*	oil	.....	.....	.....	.....	250-500	
		.....	.....	.....	.....	.....	.....	.....	optional	
		I	Yes and An.	1650-1700	in box	1325-1375†	oil			250-400
			Yes and An.	1650-1700	in box	1400-1475‡				250-400
		II	Yes and An.	1650-1700	in box	1500-1550	oil	1325-1375	oil	250-400
3115 3120	I	Yes	1650-1700	quench	1400-1450†	quench	.....	.....	250-300	
		Yes	1650-1700	quench	1450-1500‡	quench	.....	.....	250-300	
		Yes	1650-1700	in box	1400-1450†	quench	.....	.....	250-300	
		Yes	1650-1700	in box	1450-1500‡	quench	.....	.....	250-300	
		Yes	1650-1700	in box	1525-1575	oil	1375-1425	quench	250-300	
3215 3220	V	.....	1500-1650*	oil	.....	.....	.....	.....	250-500	
		.....	.....	.....	.....	.....	.....	.....	optional	
		I	Yes and An.	1650-1700	quench	1375-1425†	oil			250-500
			Yes and An.	1650-1700	quench	1425-1475‡	oil			250-500
		II	Yes and An.	1650-1700	in box	1375-1425†	oil			250-500
3312	III	Yes and An.	1650-1700	in box	1425-1475‡	oil	.....	.....	250-500	
		Yes and An.	1650-1700	in box	1525-1575	oil	1375-1425	oil	250-500	
		I	Yes and An.	1650-1700	quench	1375-1425	oil			250-300
			Yes and An.	1650-1700	in box	1375-1425†	oil			250-300
		II	Yes and An.	1650-1700	in box	1450-1500‡	oil			250-300
3415	III	Yes and An.	1650-1700	in box	1525-1575	oil	1375-1425	oil	250-300	
		Yes and An.	1650-1700	quench	.....	.....	.....	.....	250-400	
		I	Yes and An.	1650-1700	quench	1375-1425†	oil			250-300
			Yes and An.	1650-1700	quench	1450-1500‡	oil			250-300
		II	Yes and An.	1650-1700	in box	1375-1425†	oil			250-300
4615 4620	III	Yes and An.	1650-1700	in box	1450-1500‡	oil	.....	.....	250-300	
		Yes and An.	1650-1700	in box	1500-1550	oil	1375-1425	oil	250-300	
		Yes and An.	1650-1700	quench	.....	.....	.....	.....	250-400	
		I	Yes	1650-1700	quench	1425-1475†	oil			250-300
			Yes	1650-1700	quench	1475-1525‡	oil			250-300
4815 4820	II	Yes	1650-1700	in box	1425-1475†	oil	.....	.....	250-300	
		Yes	1650-1700	in box	1475-1525‡	oil	.....	.....	250-300	
		Yes	1650-1700	in box	1525-1575	oil	1375-1425	oil	250-300	
		Yes	1650-1700	quench	.....	.....	.....	.....	250-400	
		I	Yes and An.	1650-1700	quench	1350-1400†	oil			250-300
5120	II	Yes and An.	1650-1700	quench	1450-1500‡	oil	.....	.....	250-300	
		Yes and An.	1650-1700	in box	1350-1400†	oil	.....	.....	250-300	
		Yes and An.	1650-1700	in box	1450-1500‡	oil	.....	.....	250-300	
		Yes and An.	1650-1700	in box	1550-1650	oil	1350-1400	oil	250-300	
		x Yes and An.	1650-1700	quench	.....	.....	.....	.....	250-500	
6115 6120	I	Yes	1650-1700	quench	1425-1475†	oil	.....	.....	250-300	
		Yes	1650-1700	quench	1475-1525‡	oil	.....	.....	250-300	
		Yes	1650-1700	in box	1425-1475†	oil	.....	.....	250-300	
		Yes	1650-1700	in box	1475-1525‡	oil	.....	.....	250-300	
		Yes	1650-1700	in box	1600-1650	oil	1425-1475	oil	250-300	
6120	IV	.....	1500-1650*	quench	.....	.....	.....	.....	optional	
		I	Yes	1650-1700	quench	1425-1475†	oil			250-350
			Yes	1650-1700	quench	1475-1525‡	oil			250-350
		II	Yes	1650-1700	in box	1425-1475†	oil			250-350
		Yes	1650-1700	in box	1475-1525‡	oil	.....	.....	250-350	
III	Yes	1650-1700	in box	1600-1650	oil	1425-1475	oil	250-350		
6120	IV	.....	1500-1650*	oil	.....	.....	.....	.....	optional	

* = In Cyanide or activated baths. † = For case hardness only. ‡ = For core hardness. x = For fine-grained steels (E19-33).
An = Anneal after normalizing to desired machinability. Normalizing temperature should be at least 50° above carburizing temperature.



Bars racked for annealing. Note horizontal and vertical spacers to produce uniformity on heating



One of the draw benches used in cold-drawing alloy steel

NITRIDING STEELS

THE nitriding process consists of heating articles to be surface hardened in an atmosphere of ammonia gas in a gas-tight container. The articles are heated to a temperature varying from 850 to 1200 degrees F., that most commonly used being between the range of 935 to 1000 degrees F. At these temperatures an absorption of nitrogen occurs which produces a case on the surface having extreme hardness, ranging from 875 to 1200 Vickers-Brinell.

Parts to be nitrided are usually normalized and drawn, or quenched and drawn, to the desired hardness and ductility required in the core. For best results the structure should be sorbitic. Since the nitriding temperature is below the usual drawing temperature for parts which are to be machined, the operation does not affect the core properties to any appreciable extent, and produces a minimum amount of distortion. All of the decarburized surface must be removed by machining or grinding prior to the nitriding operation, or the case will crack or spall.

It has been found in general practice that some types of steels respond better to the ammonia case-hardening process and behave better in service than the usual types of alloy steels after nitriding.

Aluminum in steel has been found to rank first both as to the amount of nitrogen with which it combines and as to the stability of the nitride formed. Other elements which form nitrides in steel include chromium, vanadium, titanium, tungsten, molybdenum, and manganese.

Many of the nitriding grades of steel contain approximately 1.00 per cent aluminum. Other alloying elements used with aluminum are chromium-molybdenum, molybdenum, and nickel-chromium-molybdenum. Other grades can be nitrided but those mentioned on page 100 cover the most widely used types at the present time.

Grades of Nitriding Steel

Nitralloy Types	C.	Mn.	Si.	Ni.	Cr.	Mo.	V.	Al.
N125	0.20-0.30	0.40-0.60	0.20-0.30		0.90-1.40	0.15-0.25		0.90-1.40
N135	0.30-0.40	0.40-0.60	0.20-0.30		0.90-1.40	0.15-0.25		0.90-1.40
N230	0.25-0.35	0.40-0.60	0.20-0.30			0.60-1.00		1.00-1.50
N630	0.25-0.35	0.40-0.60	0.20-0.30		1.40-1.60		0.45 min.	
	0.25-0.35	0.40-0.70	- 0.30			0.60-1.00		0.90-1.40
	0.20-0.30	0.45-0.75	0.15-0.25	3.40-3.60	1.00-1.30	0.15-0.25		0.85-1.05

Bethlehem Steel Company has reprinted an article entitled "Nitriding" by Dr. V. O. Homerberg, Associate Professor of Physical Metallurgy, Massachusetts Institute of Technology, from the Metals Handbook, which gives the details of the operation; types of steels used; and processing recommendations. A copy will be mailed on request.



Part of the creep test equipment in the Bethlehem laboratories. Twelve additional furnaces are located in another section of the laboratory. These furnaces are held within two and a half degrees F. of the desired temperature throughout the duration of the test

STEELS FOR SERVICE AT ELEVATED TEMPERATURES

UNTIL about twenty years ago little practical or usable information was demanded about steel at elevated temperatures. With the rapid advancement of the chemical, oil and power industries during the last two decades, this question has advanced from one of scientific interest to one of paramount practical importance. Service temperatures have approached the critical ranges and consistently increasing loads have been applied.

The first attempt to gather information was carried out by what is now termed the "short-time temperature test," which is the conventional tension test of a heated test bar. In this test it was found that steels at the "blue brittle range," around 600°F. to 800°F., developed a slight increase in tensile strength, and an accompanying drop in ductility which in service was not considered serious.

The demand by engineers for more definite data on which to base their design calculations developed the fact that all steels would elongate, but at different rates, under relatively light loads when subjected to elevated temperatures for extended periods of time. This phenomenon is now termed "creep" and is recognized and given consideration by all engineers designing apparatus subjected to high temperatures in service.

"Creep" or "long-time temperature" tests develop the relation between temperature and stress that bring about a predetermined rate of flow (usually 1 per cent in 10,000 hours). The consensus of opinion at present is that "creep" tests should be of at least 1,000 hours duration.

Amid the confusion in the existing methods of conducting "creep" tests, one thing has definitely been brought out. Certain alloying elements have been found to impart desirable properties at high temperatures, either by themselves or in combination with other alloying elements. Among these, tungsten and molybdenum are outstanding.

The work of the committees of the national technical societies in standardizing "creep" testing is highly commendable. While much "creep" testing has been carried out over the past five years, the data have been developed in a more or less non-standardized manner. Some data are from accelerated tests, some are from long duration tests but on various types of machines, so that at the present time differences of opinion exist regarding the accuracy of much of the data.

Because of the unsettled conditions of the present methods of evaluating steel, by the "creep" test it is believed advisable at this time not to publish "creep" test values in this book. During the past year tentative standards have been published (A.S.T.M. E22-34T Appendix 2, E22-35T, and E21-34T) and we can look forward to uniformity of the testing procedure in the future.

Bethlehem Steel Company has had a battery of twelve "creep" test furnaces in operation since 1929. These have recently been increased by ten more of the latest and most accurate type. A background of extensive research investigations therefore augments our broad experience in practical application of steels for service at elevated temperatures.

In conducting design or engineering work where elevated temperatures are involved, it is highly advantageous for designers to have a thorough understanding of the materials available and their various limitations before the actual design is started. In such cases the selection of material to suit an arbitrary design often involves considerable difficulty. Bethlehem engineers will gladly discuss both the material and design problems in connection with steels for service at elevated temperatures.

In addition to the lower alloy content steels referred to on pages 103 and 104, produced in our alloy mill, Bethlehem also produces in the Tool Steel department, the high chromium, high nickel-chromium, high chromium-molybdenum, and chromium-tungsten types of steel for service at elevated temperatures.

SUPERTEMP ALLOY STEEL

Supertemp is a chromium-tungsten alloy steel developed by the Bethlehem Steel Company for service at temperatures up to and including 1050° F. It retains an exceptional amount of strength at elevated temperatures and is an ideal steel for parts which must have high creep characteristics combined with resistance to both oxidation and fatigue.

This steel has been widely used for bolts, studs, and refinery parts where high pressures and temperatures are encountered. A record of over seven years of successful service confirms in a practical manner our laboratory findings and serves as an excellent recommendation for this steel.

TABLE OF PHYSICAL PROPERTIES AT ROOM TEMPERATURE

Actual value of 1" round bar

	Annealed	Quenched, 1200° F. Draw	Coefficient of Linear Expansion
Yield Point, lbs. per sq. in.	68,000	132,000	78 to 200 deg. F.. 0.00000615
Tensile Strength, lbs. per sq. in.	100,000	148,000	78 to 500 deg. F.. 0.00000677
Elongation in 2", per cent.	25	19	78 to 1000 deg. F.. 0.00000737
Reduction of Area, per cent.	60	58	
Brinell.	201	302	

CHROMIUM-MOLYBDENUM STEELS

The S. A. E. 4140 steel is used where actual temperatures do not exceed 900° F. As 1000° F. is approached, the strength of this alloy falls off rapidly and it is therefore not recommended for service at this high temperature. Increasing the molybdenum content above the S. A. E. range will improve the high temperature properties.

PHYSICAL PROPERTIES AT ROOM TEMPERATURE, OF 4140

Actual values of 1" round bar

	Annealed	Oil Quenched, 1200° F. Draw	Coefficient of Linear Expansion
Yield Point, lbs. per sq. in.	63,000	126,000	78 to 200 deg. F.. 0.00000627
Tensile Strength, lbs. per sq. in.	87,000	146,000	78 to 500 deg. F.. 0.00000677
Elongation in 2", per cent.	27	17	78 to 1000 deg. F.. 0.00000741
Reduction of Area, per cent.	57	56	
Brinell.	179	285	

CARBON-MOLYBDENUM STEELS

For many types of service, material is required, the normal room temperature physical characteristics of which must be

approximately maintained while at elevated service temperatures. Safe weldability is also a very important factor. For this type of service, carbon-molybdenum alloy steels are widely used. To obtain the maximum physical properties of these steels at high temperatures, balance between carbon, manganese, and molybdenum is essential. Reasonable additions of manganese to carbon-molybdenum steel tends to improve high-temperature properties without unduly increasing air-hardening properties or seriously interfering with weldability. A manganese content ranging between 0.70 and 1.20 per cent is often used. In the cases of higher manganese content, proportionately lower carbon is desired.

A very popular composition for this type of service is the following: C. 0.30 per cent max., Mn. 0.70 per cent max., Mo. 0.40 to 0.60 per cent, with the proviso that for every decrease of 0.01 per cent of carbon, an increase of manganese of 0.025 per cent will be allowed. The following approximate composition is considered a good one: C. 0.20 per cent, Mn. 0.90 per cent, Mo. 0.50 per cent.

PHYSICAL PROPERTIES AT ROOM TEMPERATURE

Actual values of 1" round bar

	Annealed	Oil Quenched, 1100° F. Draw	Coefficient of Linear Expansion	
Yield Point, lbs. per sq. in.....	46,000	83,000	78 to 200 deg. F..	0.00000656
Tensile Strength, lbs. per sq. in...	73,000	103,000	78 to 500 deg. F..	0.00000693
Elongation in 2", per cent.....	31.5	25	78 to 1000 deg. F..	0.00000750
Reduction of Area, per cent.....	59	56		
Brinell.....	146	212		

BETHLEHEM MAYARI "A" — S. A. E. 3135

This nickel-chromium steel was an early type of alloy steel to be recommended for service at elevated temperatures. It is now used for many types of service where temperatures are not excessive.

PHYSICAL PROPERTIES AT ROOM TEMPERATURE

Actual values of 1" round bar

	Annealed	H ₂ O Quenched, 1100° F. Draw	Coefficient of Linear Expansion	
Yield Point, lbs. per sq. in.....	63,000	105,000	78 to 200 deg. F..	0.00000640
Tensile Strength, lbs. per sq. in...	97,000	127,000	78 to 500 deg. F..	0.00000695
Elongation in 2", per cent.....	30	22	78 to 1000 deg. F..	0.00000740
Reduction of Area, per cent.....	57	60		
Brinell.....	201	262		

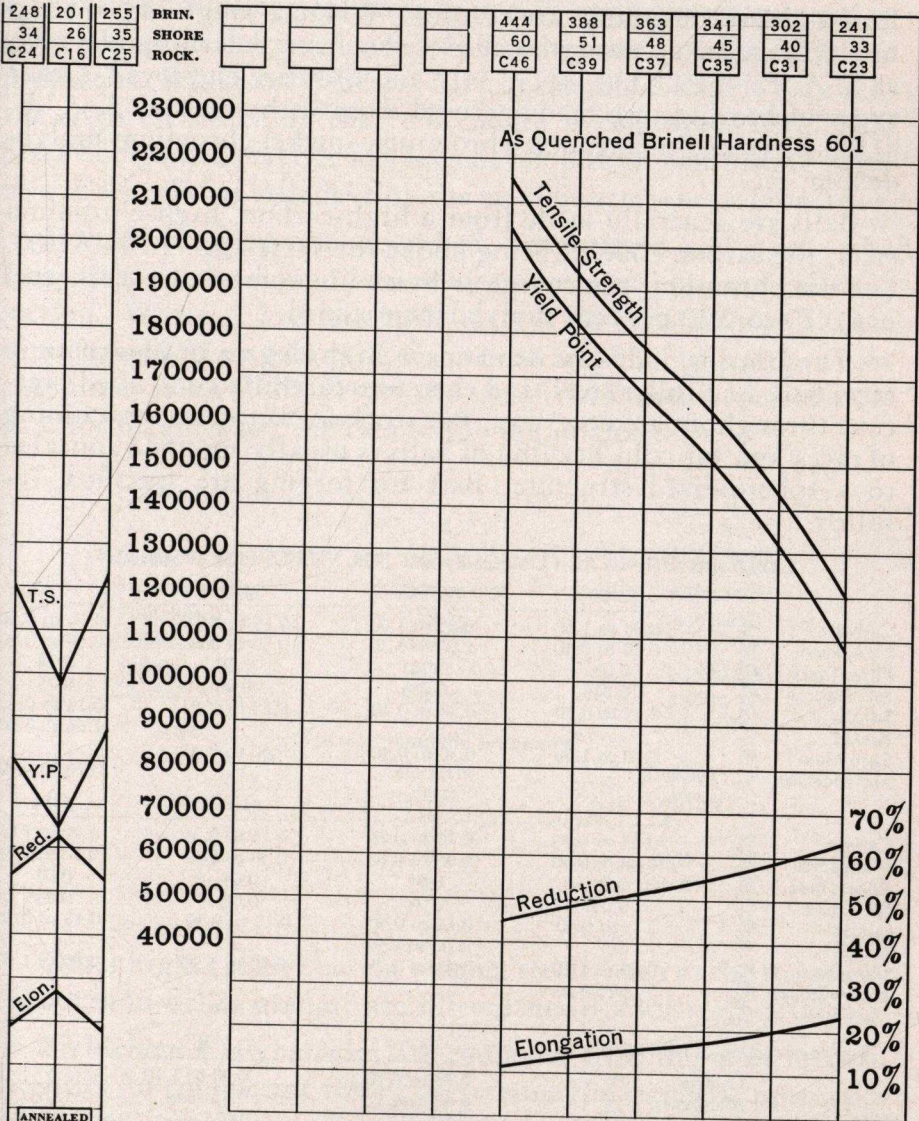
PHYSICAL PROPERTIES CHART

SUPERTEMP
(Average Values)

SUPERTEMP

1" Dia. SIZE TREATED

.505" x 2" SIZE TESTED



ANNEALED 1450°F.C. QUENCH _____ 1625°F. 1625°F. 1625°F. 1625°F. 1625°F. 1625°F.

AS ROLLED NORM. L2D 1650°F.C. DRAW _____ 800°F. 900°F. 1000°F. 1100°F. 1200°F. 1300°F.

NORMALIZED 1650°F.C. _____ QUENCHED IN OIL _____

BEARING STEELS

A LARGE tonnage of high-grade steels for races, rollers and balls is used by the ball-and roller-bearing industry. The steel most commonly used for races is S. A. E. 52100, where great load and wear resistance are required. Where a tough interior and hard surface are necessary because of shock, carburizing steels such as S. A. E. 4615, 5120, 3115, 3312 and 6120 are employed. Other types of bearings are manufactured from such steels as S. A. E. 4150, 6195 and manganese-chromium, nickel-chromium-molybdenum, etc.

Balls are generally made from a high-carbon, high-chromium steel, the carbon content being about the same as S. A. E. 52100, but the chromium percentage is lower. In some cases, this steel has 0.20 to 0.30 per cent molybdenum added.

The bearing industry demands a high degree of cleanness in race, ball, and roller steel, and therefore carefully controlled practices throughout are necessary. Bar stock for automatic machining of races and for cold heading of balls is usually specified annealed to a spheroidized structure. Bars for forging are specified "as rolled."

TABLE OF CHEMICAL COMPOSITIONS FOR STEELS FOR BEARINGS

		52100	Mn.-Cr.	5120	4615
Carbon	%	0.95 to 1.10	0.85 to 1.00	0.15 to 0.25	0.10 to 0.20
Manganese	%	0.20 to 0.50	1.00 to 1.30	0.30 to 0.60	0.40 to 0.70
Phos. (max.)	%	0.03	0.03	0.04	0.04
Sul. (max.)	%	0.035	0.035	0.05	0.05
Silicon	%	0.15 to 0.30	0.20 to 0.40	0.15 to 0.30	0.15 to 0.30
Nickel	%	....	....	....	1.65 to 2.00
Chromium	%	1.20 to 1.50	0.30 to 0.50	0.60 to 0.90	....
Molybdenum	%	....	....	....	0.20 to 0.30
		4150	3115	6120	6195
Carbon	%	0.45 to 0.55	0.10 to 0.20	0.15 to 0.25	0.90 to 1.05
Manganese	%	0.60 to 0.90	0.30 to 0.60	0.30 to 0.60	0.20 to 0.45
Phos. (max.)	%	0.04	0.04	0.04	0.03
Sul. (max.)	%	0.05	0.05	0.05	0.035
Silicon	%	0.15 to 0.30	0.15 to 0.30	0.15 to 0.30	0.15 to 0.30
Nickel	%	....	1.00 to 1.50	....	....
Chromium	%	0.80 to 1.10	0.45 to 0.75	0.80 to 1.10	0.80 to 1.10
Molybdenum	%	0.15 to 0.25	....	....	....
Vanadium	%	....	....	0.15 min.	0.15 min.

The composition of ball steels is as follows:— "A"

		"A"	"B"
Carbon	%	0.90 to 1.10	0.90 to 1.10
Manganese	%	0.50 max.	0.50 max.
Phosphorus	%	0.025 "	0.025 "
Sulphur	%	0.025 "	0.025 "
Silicon	%	0.15 to 0.30	0.15 to 0.30
Chromium	%	0.75 to 1.20	0.75 to 1.20
Molybdenum	%	....	0.20 to 0.30

MAGNET STEELS

SPECIAL metallurgical practice in mill operations is required in making steel for magnets. Full annealing impairs magnetic properties. Where cold shearability or machinability is required, the slightest softening that will suffice is employed. Bethlehem Steel Company's practice has been developed for controlling hardness in a steel that will develop the maximum magnetic properties.

Formed magnets are quenched, magnetized and aged. The quenching is done in oil or water depending on analysis and section. Where a low strength magnet is satisfactory, a steel containing 0.55 to 0.65 per cent carbon and 0.70 to 1.00 per cent chromium is used. However, the usual chromium types of steel used for magnets are the two following grades:

	A	B
Carbon %	0.90 to 1.00	0.90 to 1.00
Manganese %	0.20 to 0.50	0.20 to 0.50
Phosphorus %	0.04 max.	0.04 max.
Sulphur %	0.04 "	0.04 "
Silicon %	0.15 to 0.30	0.15 to 0.30
Chromium %	2.00 to 2.50	3.50 to 4.00

Typical magnetic properties*

	Coercive Force H_c	Residual Induction B_r
A.	52	9000
B.	60	9500

Other higher alloy content magnet steels, such as the tungsten, cobalt, and other grades, are offered under tool steel products.

Bethlehem's laboratories are equipped with the most modern facilities for conducting tests to determine the magnetic properties of steel prior to shipment.

*See also page 181.

ALLOY GEAR STEELS

THE demand of the modern automobile, airplane and other highly specialized mechanisms, has required the development of thoroughly reliable gears.

Steel used for this purpose may be divided into two main classifications—carburizing type steels and oil-hardening type steels.

CARBURIZING TYPE STEELS

Alloy steels of many different analyses have been used in carburizing, such as the $\frac{1}{2}$, $1\frac{1}{2}$, $3\frac{1}{2}$ and 5 per cent nickel, nickel-chromium, chromium-vanadium and nickel-molybdenum steels.

One phase of the carburizing type of steel which requires close attention is the inherent grain size of the steel at a definite temperature. This is discussed on pages 95 and 123.

In production work, good machinability and minimum distortion are of paramount importance. It is, therefore, recommended, especially for ring gears, that after the hot-forming operations, the forgings be given a thorough annealing at a temperature between 1750° F. and 1850° F. The forgings should be slowly heated to the annealing temperature, held at this temperature at least two hours for each inch of thickness and then cooled slowly and uniformly to approximately 600° F. From this temperature they may be air cooled to room temperature.

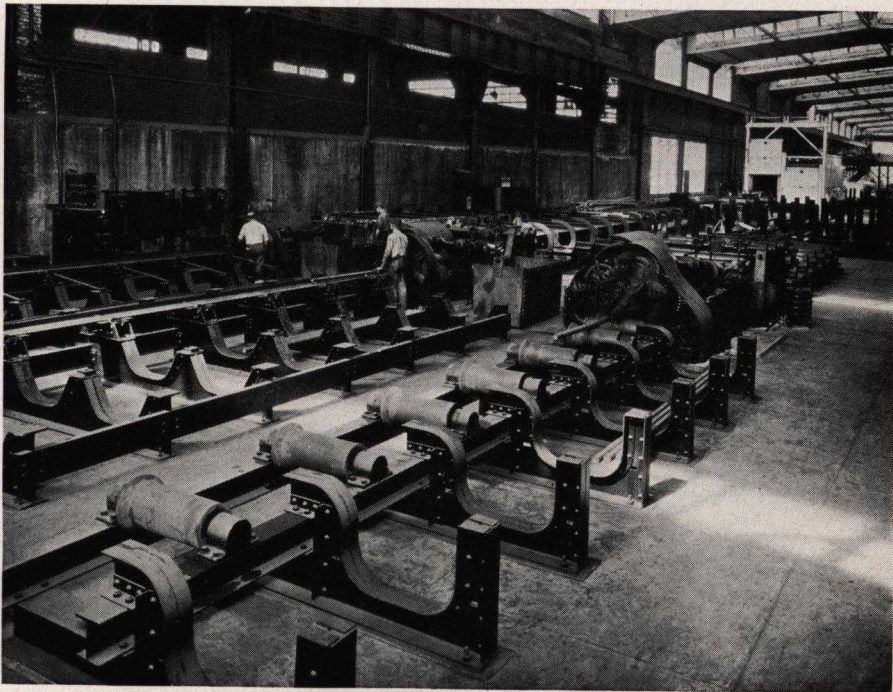
The subsequent treatment required after machining is fully covered under the heading "Carburizing Steels," on page 95.

OIL-HARDENING TYPE STEELS

The oil-hardening types of Alloy Gear Steels have carbon contents varying from 0.45 to 0.60 per cent. The $3\frac{1}{2}$ per cent nickel, nickel-chromium, nickel-molybdenum, chromium, chromium-molybdenum, chromium-vanadium and nickel-chromium-molybdenum steels are all highly satisfactory for this service, the choice depending on the conditions under which they will operate.

Normalizing at 1600° to 1650° F. after hot forming is recommended for all the oil-hardening alloy gear steels. This operation is necessary for both machinability and response to subsequent heat treatment. The parts should be held at the normalizing temperature at least one hour for each inch of thickness. The rate of cooling that is used has considerable effect on the results of this conditioning treatment and it is recommended that from 1200° F. the cooling be carried out slowly. If the optimum in the conditioning treatment is desired, the forgings should be air cooled from the normalizing temperature and immediately annealed at 1200 to 1250° F., holding one hour per each inch of thickness, with furnace cooling. This will put the steel in its best condition for machining, with minimum distortion and maximum response to the final heat-treatment operation.

The recommended S. A. E. temperatures for the final oil quench are shown in Part 1 of this book.



One of the batteries of straightening machines

TOOLS AND MACHINE PARTS

BETHLEHEM Steel Company has had practical experience in the production of alloy and special requirement steels for many uses. The knowledge gained in producing steels of the proper quality for unusual purposes is put to practical application in processing the steel for tools and machine parts.

EDGE-TOOLS

A considerable quantity of alloy steel is used for edge-tools such as axes, hatchets, machetes, chisels, pipe cutters, pliers, etc. In general, with only one alloying element present, the carbon ranges are in the higher brackets—0.70 to 1.00 per cent; and when two or more alloying elements are present, the carbon is lower—0.45 to 0.65 per cent. The steels are quenched in brine, water or oil, depending on section, analysis, and cutting requirements.

Such steels are (a) S. A. E. 4150, (b) S. A. E. 6150, (c) S. A. E. 9260 and (d) those with one alloying element such as vanadium, chromium or molybdenum with ranges somewhat as follows:

Carbon, per cent	0.70 to 1.00
Manganese, per cent	0.50 max.
with either Vanadium, per cent	0.15 min.
or Molybdenum, per cent	0.15 to 0.30
or Chromium, per cent	0.40 to 0.90

Table of Uses for Edge-Tools

	(a)	(b)	(c)	(d)
Chisels.....	X	X	X	X
Axes.....	..	..	..	X
Hatchets.....	..	..	..	X
Machetes.....	..	..	..	X
Pipe Cutter Wheels.....	X	X	X	X
Pliers.....	X	X	..	X

X indicates the use to which each grade is put.

FILES

Files are strictly edge-tools and each of the thousands of teeth must continue to function, when properly used, without appreciably dulling throughout the life of the file. Other edge-tools can be ground when dulled to prolong their serviceability.

File steel, generally ranging from 1.00 to 1.50 per cent carbon, when annealed must have the quality of taking sharp, uniform and continuous teeth. In hardening, the steel must respond to the quenching operations so that the teeth are hard with good cutting properties.

Decarburized surface on a finished file is obviously fatal. The rolled section, in addition to having practically no decarburization, must be straight and uniform so that in processing, all grinding and tooth-forming operations must work to relatively the same depth under the original skin of the bar and the teeth must be in metal of the proper and uniform chemical analysis.

The production of high-quality file steel may properly be termed an art. Bethlehem Steel Company has produced large tonnages of this grade of steel over a number of years and has kept in step with the demands of the high-quality file producers.

COLLETS

In this group of screw or lathe machine tools are included feed fingers, pads and collets. Various types of steels are used for these parts, ranging from "Bethlehem Special Collet Steel," a tool steel grade, to the lower alloy content steels covered by this publication. This use of alloy steels includes such grades as S. A. E. 2350, 3245, 4150 and 6150 for the oil-hardening type which produces a Rockwell hardness of approximately C 55; and S. A. E. 2315, 3115 and 4620, carburized, which attain a Rockwell hardness of approximately C 60 on the face and approximately C 40 on the threaded end; all with heat treatment. Properties required of any grade of steel to make a good collet are as follows:

- (a) Ability to obtain sufficient hardness on quenching.
- (b) Good machinability.
- (c) Minimum distortion in treatment.
- (d) Ability, with proper hardness, to stand reasonable compression and spreading by springing.
- (e) Ease of threading in treated condition.

SHAFTING

In many cases, modern machine design involves the replacement of the older type shafting with alloy steel. For this work, oil or water-hardening steels are generally used. The manganese,

nickel, nickel-chromium, chromium-molybdenum, nickel-chromium-molybdenum and chromium-vanadium steels are all used. For the larger heat-treated shafts it is very desirable that the shaft be hollow bored prior to treatment. In all shafting where there are changes of diameters, it is extremely important that there should be fillets with radii as large as possible.

GEARS AND PINIONS

Two types of steel are used in this service—the high-carbon (0.40 to 0.55 per cent) oil-hardening alloy grades and the low-carbon carburizing alloy grades. Alloy steel is used for gears and pinions where high tooth load is encountered combined with high peripheral speed. In cases where a small pinion is engaged with a large gear, it is suggested that the pinion be somewhat harder to counteract its greater wear.

WRENCHES AND ACCESSORIES

For use around machines where strength and light weight are required, alloy steel wrenches are now usually chosen. Wrenches are commonly forged from bar stock at relatively low temperatures, then annealed for machinability and structure prior to machining, and heat treated to develop hardness, strength, and wear resistance with satisfactory toughness. Frequently the wrenches are plated as a final operation. Wrenches require a steel with good surface and internal uniformity for reliability in service. The steels commonly used are the carburizing grades (S. A. E. 3120 and 6120) and the liquid-hardening grades (S. A. E. 3140, 4140, 4640 and 6140). Other special steels and modifications of S. A. E. steels are used, chiefly of the oil-hardening grades.

Pipe cutter wheels are usually of an oil-hardening type of steel such as S. A. E. 4150, 6150 or 9260.

Steels of the S. A. E. 4150, 4640 and 6150 type have given excellent results when used for screwdrivers. The screwdrivers are generally processed from annealed, cold-drawn stock, the blades formed by either hot or cold forging. Heating for oil quenching is usually done in salt or lead baths so that the distance hardened from the blade end can be controlled.

ALLOY STEELS FOR RAILROAD SERVICE

THERE is a growing justification for the use of alloy steels in the railroad field, for the purpose of saving weight and improving performance. There are five general applications: locomotive forging steels; engine and superheater bolt steels; stay-bolt steels; spring steels; and miscellaneous uses.

Locomotive Forging Steels—Forgings for uses such as main rods, side rods, piston rods, axles, etc., are usually treated by normalizing (air-cooling) and drawing (furnace-cooling) although in some instances quenching and drawing is employed.

The compositions generally used are as follows:

		C.-V.	Nickel		Mn.-V.	Cr.-V.	Cr.-Va.
C.	%	0.45 to 0.55	0.20 to 0.27	0.25 to 0.35	0.18 to 0.25	0.28 to 0.42	0.38 to 0.45
M.	%	0.70 to 1.00	0.70 to 1.00	0.70 to 1.00	1.55 to 1.85	0.40 to 0.80	0.60 to 0.90
P. (max.)	%	0.045	0.045	0.045	0.045	0.04	0.04
S. (max.)	%	0.05	0.05	0.05	0.05	0.04	0.04
Si.	%	0.15 to 0.30	0.15 to 0.30	0.15 to 0.30	0.15 to 0.30	0.10 to 0.30	0.10 to 0.30
Ni.	%	.....	2.50 to 3.00	2.50 to 3.00	.....	.....	.....
Cr.	%	0.25 max.	.....	.....	.....	0.80 to 1.25	0.80 to 1.25
V.	%	0.18 min.	.....	.....	0.15 min.	0.15 min.	0.15 min.

Properly treated forgings will have approximately the following properties:

	C.-V.	Ni.	Ni. (x)	Mn.-V.	Cr.-V.	Cr.-V. (x)
Tensile Strength, lbs. per sq. in.....	90,000	80,000	95,000	90,000	90,000	95,000
Yield Point, lbs. per sq. in.....	58,000	55,000	65,000	60,000	60,000	65,000
Elongation, per cent in 2".....	20.0	28.0	22.0	25.0	22.0	20.0
Reduction of Area, per cent.....	40.0	58.0	50.0	50.0	45.0	50.0

Above results represent the normalized and annealed condition except those marked (x) which are quenched and drawn.

Engine bolt and Staybolt Alloy Steels—The following types are in general use:

		2015	2115	3130	Staybolt
Carbon	%	0.10 to 0.20	0.10 to 0.20	0.25 to 0.35	0.10 max.
Manganese	%	0.30 to 0.60	0.30 to 0.60	0.50 to 0.80	0.40 max.
Phosphorus (max.)	%	0.04	0.04	0.04	0.04
Sulphur (max.)	%	0.05	0.05	0.05	0.05
Silicon	%	0.15 to 0.30	0.15 to 0.30	0.15 to 0.30	0.15 max.
Nickel	%	0.40 to 0.60	1.25 to 1.75	1.00 to 1.50	1.25 to 1.75
Chromium	%	.....	.....	0.45 to 0.75	.....

The S. A. E. 2015, 2115 and staybolt steels are generally used in the "as-rolled" condition, having the following minimum physical properties:

	2015		2115		Staybolt
	Up to 1" rd.	Over 1" rd.	Up to 1"	Over 1"	
Tensile Strength, lbs. per sq. in...	55,000	50,000	65,000	60,000	55,000
Yield Point, lbs. per sq. in.....	35,000	30,000	45,000	40,000	35,000
Elongation, per cent in 2".....	28.0	25.0	28.0	25.0	32.0
Reduction of Area, per cent.....	55.0	50.0	55.0	50.0	62.0

Mayari steel is furnished in Staybolt, Enginebolt and Superheater bolt grades with the following minimum physical properties:

	Mayari Staybolt	Mayari Enginebolt up to 1"	Mayari Enginebolt over 1"	Mayari Superheater Bolt
Tensile Strength, lbs. per sq. in....	55,000	65,000	60,000	110,000
Yield Point, lbs. per sq. in.....	35,000	45,000	40,000	90,000
Elongation, per cent in 2".....	32	28	25	20
Reduction of Area, per cent.....	62	55	50	55

The properties given for superheater bolts represent heat-treated steels. The properties of the others in their natural condition.

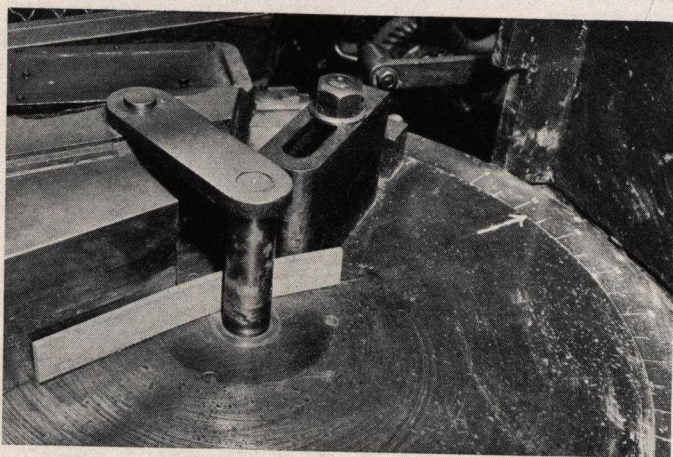
Alloy Spring Steels—These steels are used in helical and elliptical springs and are generally of the following compositions:

		Si.-Mn.	Cr.-V.	Si.-V.
Carbon	%	0.55 to 0.65	0.50 to 0.60	0.85 to 1.00
Manganese	%	0.60 to 0.90	0.60 to 0.90	0.40 to 0.70
Phosphorus (max.)	%	0.045	0.045	0.045
Sulphur (max.)	%	0.045	0.045	0.045
Silicon	%	1.80 to 2.20	0.15 to 0.30	0.50 to 0.75
Chromium	%	.....	0.80 to 1.10	.....
Vanadium	%	.....	0.15 min.	0.15 min.

These steels, after forming, are reheated and oil quenched, then drawn to obtain 2.9 to 3.1 m.m. diam. Brinell hardness.

Other alloy steels for springs are available when desired.

Miscellaneous—Alloy steels are used for other miscellaneous parts such as keys, pins, studs, guides, pump shafts, gears, bushings, carburized parts for sliding members, etc.



A $\frac{1}{4}$ in. x $1\frac{3}{4}$ in. bar of silico-manganese spring steel heat treated to Brinell hardness of 415 (3.0 m.m. diam.), shown locally bent $12\frac{1}{2}$ degrees around a 2 inch diameter pin without taking a permanent set

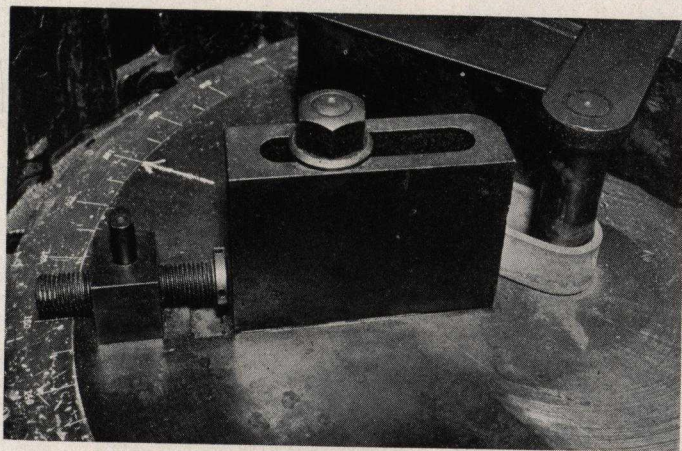
SPRING STEELS

SPRINGS, both elliptical and helical, are practically all fabricated from the grades of steel shown in the table on page 116. Special care in rolling is exercised to obtain cold shearing qualities and, in the case of the flat sections, punching and trimming qualities. Accuracy in size and straightness and good surface are important factors.

The utility of a spring is measured by its resilience and endurance under given loads, and the limitations lie in both the material and design. A spring subjected to sudden bend or torque must possess a good combination of strength, elasticity and ductility.

Steel which has been fabricated into springs is usually, after quenching, drawn to a Brinell hardness of from 388 to 444 (3.1 to 2.9 m.m. diam.).

The function of a spring is to dissipate energy mainly through internal strain friction within the elastic limit of the material. If the stresses are light, the life of the spring will be long. If the stresses are heavy and of high frequency, even though within the elastic limit of the steel, the duration of life is shortened.



A $\frac{1}{4}$ in. x $1\frac{3}{4}$ inch bar of silico-manganese spring steel heat treated to Brinell hardness of 415, (3.0 m.m. diam.), shown locally bent 180 degrees around a 2 inch diameter pin without cracking

It is a peculiarity of metal that, given time, it will recover after applications of stresses within the elastic limit. The so-called "fatigue" develops when there is insufficient time for recovery. Proper methods of manufacture and effective heat treatment can minimize this effect and aid in prolonging the life of a spring.

In the hardening of springs, variation in results obtained depend on the size of the section treated and the effectiveness of the quenching operation. Bethlehem Steel Company endeavors to eliminate one of the variables by giving careful consideration to the hardening elements of the steel used for different sizes, so that as far as possible, with the same treatment under the same conditions, the hardness of the different spring steel sections in the heat-treated condition will be about the same.

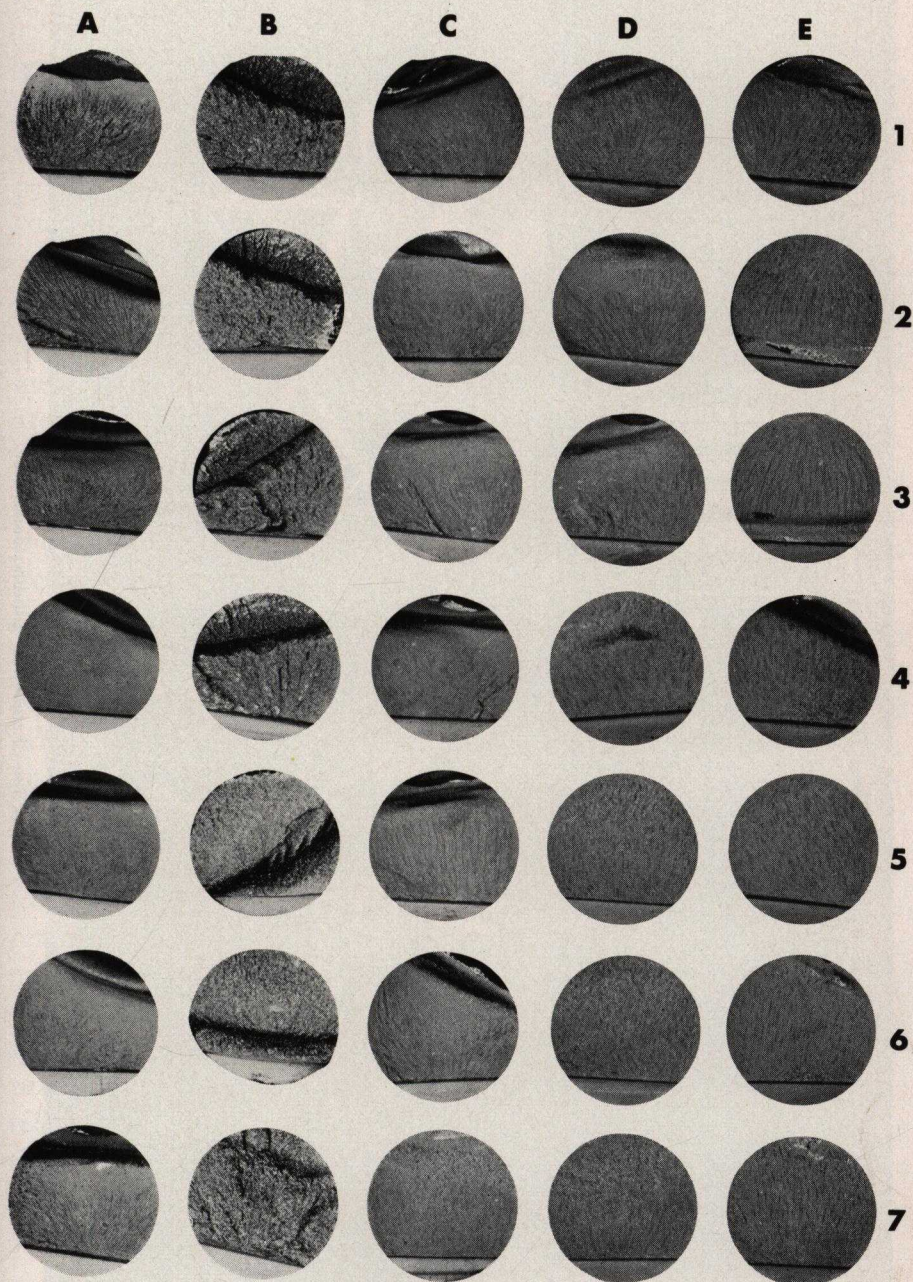
The selection of proper spring steel, therefore, involves more than a knowledge of the chemistry and the tensile properties of the steel in the heat-treated condition. Bethlehem Steel Company, having produced many thousand tons of spring steel of various analyses, and with the proper equipment and special care, is able to furnish the highest quality spring steel.

		Carbon	C.-Cr.	Si.-Mn.	Cr.-V.
Carbon	%	0.90-1.05	0.45-0.55	0.50-0.65	0.45-0.55
Manganese	%	0.25-0.50	0.70-1.00	0.60-0.90	0.60-0.90
Phosphorus (max.)	%	0.04	0.04	0.04	0.04
Sulphur (max.)	%	0.055	0.05	0.05	0.05
Silicon	%	0.10-0.25	0.10-0.25	1.80-2.20	0.15-0.30
Chromium	%	.....	1.00-1.30	.....	0.80-1.10
Vanadium	%	.....	.....	.....	0.15 min.
		Cr.-Mo.	Cr.-Si.-Mn.	C.-Mo.	Si.-V.
Carbon	%	0.45-0.55	0.45-0.55	0.62-0.72	0.85-1.00
Manganese	%	0.60-0.90	0.60-0.90	0.65-0.95	0.40-0.70
Phosphorus (max.)	%	0.04	0.04	0.04	0.04
Sulphur (max.)	%	0.05	0.05	0.05	0.05
Silicon	%	0.15-0.30	0.40-0.60	0.15-0.30	0.50-0.75
Chromium	%	0.80-1.10	0.65-0.95	.....	.....
Vanadium	%	.....	.....	.....	0.15 min.
Molybdenum	%	0.15-0.25	.....	0.10-0.25	.....

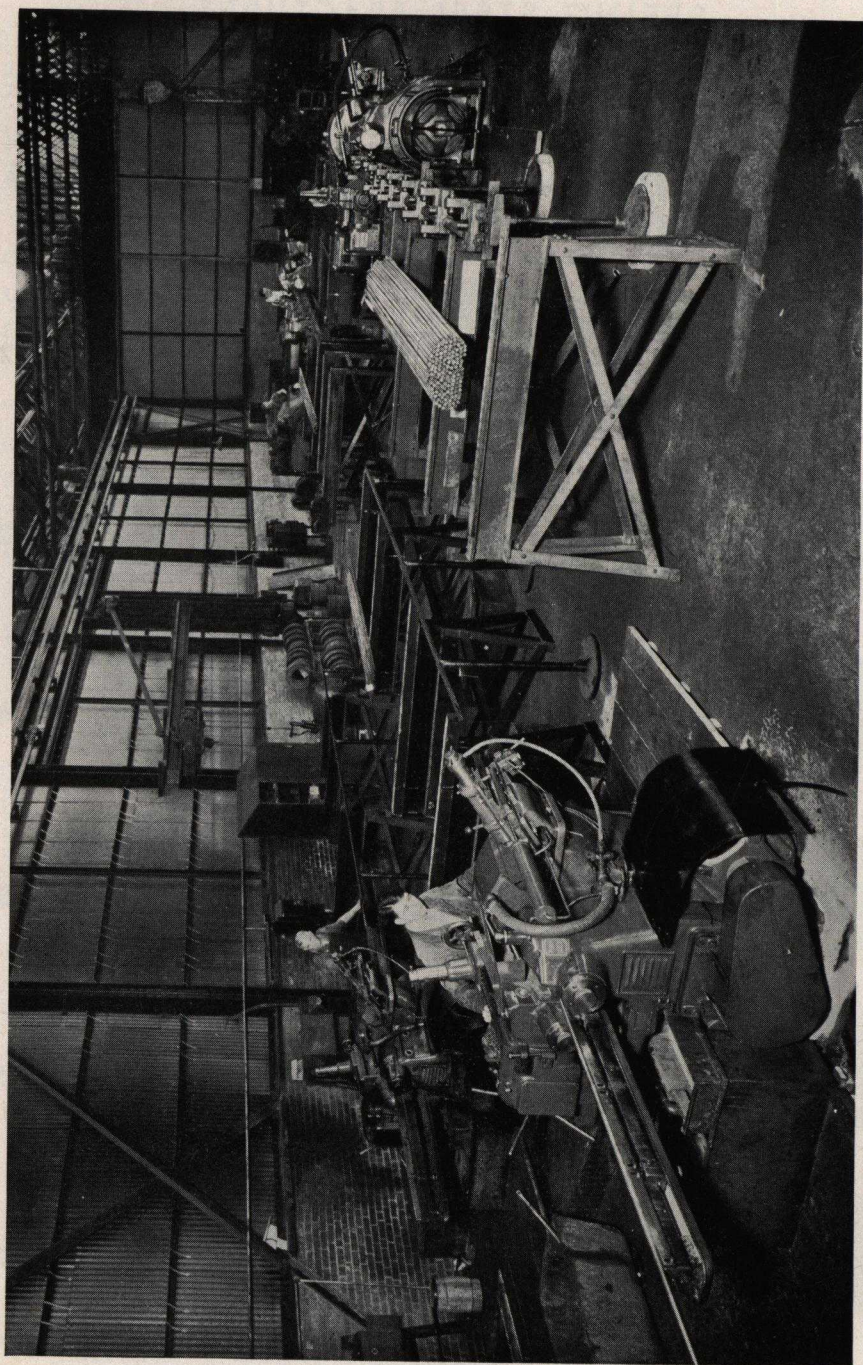
KEY TO SPRING STEEL FRACTURES ON PAGE 117

Quench	Chromium-Vanadium	Carbon	Carbon-Molybdenum	Silico-Manganese	Chromium
1400°F.	A-1	B-1	C-1	D-1	E-1
1450 "	A-2	B-2	C-2	D-2	E-2
1500 "	A-3	B-3	C-3	D-3	E-3
1550 "	A-4	B-4	C-4	D-4	E-4
1600 "	A-5	B-5	C-5	D-5	E-5
1650 "	A-6	B-6	C-6	D-6	E-6
1700 "	A-7	B-7	C-7	D-7	E-7

SPRING STEEL FRACTURES



Fractures of various types of spring steel in the "as quenched" condition



Section of centerless grinding department

AIRPLANE QUALITY STEELS

EXTRA precautions are essential in the production of steels for airplane engine parts. This is mainly due to the fact that it is necessary in such construction to have the lowest possible weight per horse-power with unfailing reliability, because of service conditions and hazards.

Each finished part must be inspected with extreme care. In many cases, in addition to the usual methods of preparing steel for inspection, such as pickling, sand or shot blasting, unusual methods of checking such as magnetic analysis or X-ray inspection are carried out.

To meet the unusually severe requirements, the steel must be of high quality, insuring maximum uniformity, cleanness, and the requisite inherent characteristics to get the desired results from heat treatment.

Airplane quality steel requires unusually heavy discard, so that, in addition to the normal crop, a further loss of 25 to 35 per cent is involved. Double pickling and chipping of blooms and billets is necessary. For many parts, the bar steels must be pickled and all very slight defects removed, or the stock must be rough turned or ground.

Bethlehem airplane quality steels have been proved in service for more than ten years. During this period there has been a remarkable development in reliability and increased power per unit of weight in the engines of all leading builders. In this marked expansion and in the constantly improved records in speed and endurance in which American-built engines have had a part, including Lindbergh's flight to Paris on May 21, 1927, Bethlehem airplane quality steels played an active part. They were then, and are today being used, in many of the vital parts.

STEELS FOR THE OIL INDUSTRY

THE rapid advances of the oil industry have required the use of much heat-treated alloy steel. Conditions present new problems daily in the drilling of wells ten thousand feet deep, the pumping from wells seventy-five hundred deep, and the presence of bad acid, hydrogen sulphide, salt water or electrolytic conditions. In the modern refinery the increased pressures and temperatures used require alloy steel of the highest quality.

Some of the proven applications of alloy steel in drilling and pumping are as follows:

S. A. E. 3115, 2315, 4615 Carburized and hardened

Rock drill and reamer cutters	Fishing tools
Reamer and drill collar pins	Slip inserts
Rotary machine gears	Cones
Slush pump piston rods	Die collars

S. A. E. 3140 Quenched and drawn

Drill bodies	Reamers
Casing perforators	Tool joints
Casing cutters	Drill collars
Kelley bars	Slush pump piston rods

S. A. E. 2340 Quenched and drawn

Jar bodies and drill collar pins

S. A. E. 3250 Quenched and drawn

Reamer and drill collar pins

S. A. E. 4130 Quenched and drawn

Polish rods

S. A. E. 1330 Fully normalized

Pull rods

Bethlehem Steel Company makes two grades of sucker rods to meet the various operating and well conditions; Mayari for corrosive wells, and XX Copper-bearing for non-corrosive wells. In both grades the rods are normalized for their full length.

Steel for refinery service of the types described in this book usually involve elevated temperature conditions and these are described on pages 101 to 105.

PART 3

**TESTING AND PROPERTIES
OF STEELS**

GRAIN SIZE—A. S. T. M.

P-F TEST

EFFECT OF COLD DRAWING ON TENSILE
PROPERTIES OF ALLOY STEEL

EFFECT OF SIZE OF TEST BAR

EFFECT OF MASS ON PROPERTIES OF
HEAT-TREATED STEEL

ENDURANCE STRENGTH OF STEEL

DEFLECTION OF STEEL UNDER STRESS

STEEL AT LOW TEMPERATURES

IRON-CARBON DIAGRAM

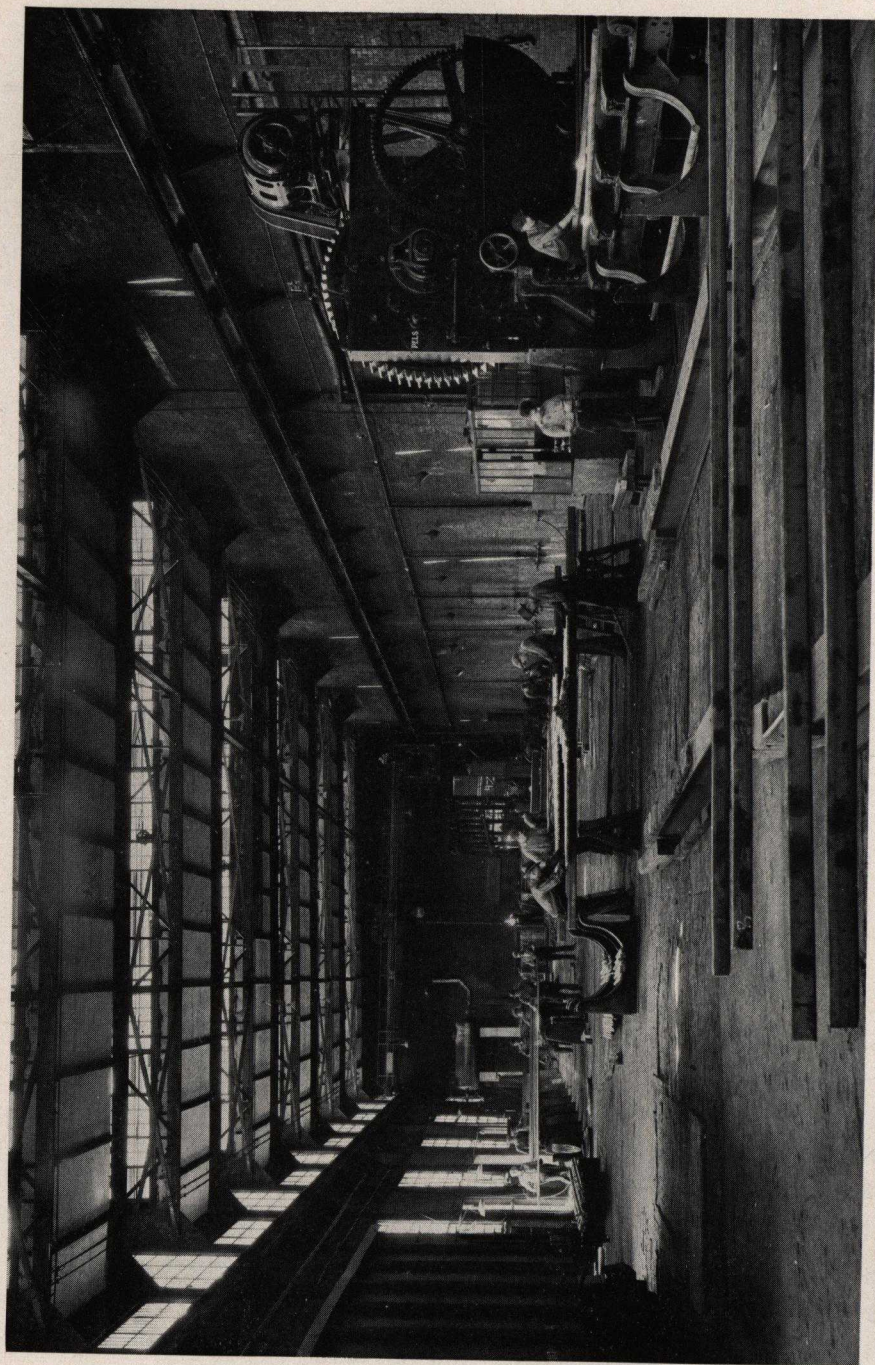
CHEMISTRY

COMPOSITION HARDNESS

HOT ACID ETCHING

TENSION TEST TERMS

UNITS USED IN THE MEASUREMENT
OF PERMANENT MAGNETS



Section of the inspection bay showing shear, bench, spot chipping and grinding inspection, spot and spark testing

GRAIN SIZE

A. S. T. M. (E19-33) CARBURIZING TEST

BETHLEHEM Steel Company, among the pioneers in this method of evaluating steels which are to be subsequently heat treated, has studied this problem since 1922 and has made practical application of this knowledge to its products for better performance.

A number of investigators have been studying this method of evaluation and the performance response, and as a result have brought forth many variations and changes since the test was originally proposed. Much progress has been made up to the present time but considerable further knowledge is necessary both from the research and performance viewpoint before a final method of practical application is set up.

In the early application of this test the terms "normal" and "abnormal" were inadvertently used to describe the condition of the grain boundaries. These rather misleading terms led to considerable confusion, since the condition defined by "abnormal" steel in this instance did not necessarily refer to steel of inferior or questionable quality. These terms at the present time are not used as often as formerly since more attention is paid to grain size.

This test is used primarily to classify steels in accordance with their response to one definite heat treatment. Steels are classified according to grain size after being carburized at one established temperature. For classifying, the grain size of the case is always used, although some tests also include a record of the core, or the transition zone grain size.

By grain size regulation or control, is meant, the production of either coarse or fine-grained steels for specific purposes.

Using our present knowledge of the art, we can make two classifications, "coarse-grained steels" and "fine-grained steels" as set forth in E19-33, American Society for Testing Materials. The influence of normality on the properties of coarse and fine-grained steels, has not been definitely proven.

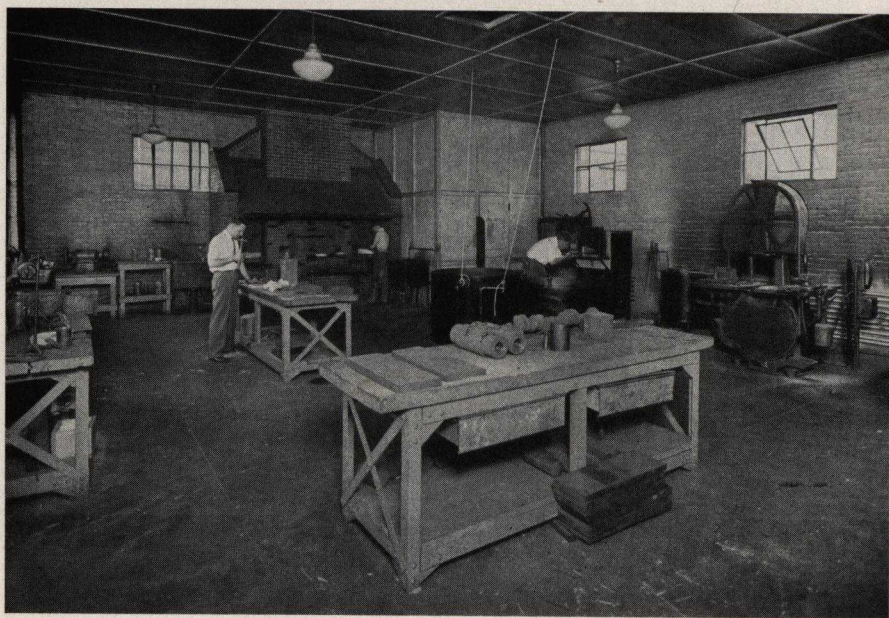
"Coarse-grained steels" have, in general, been found to possess inherently deeper hardening properties and to respond better

than "fine-grained steels" when subjected to liquid quenching. "Coarse-grained steels" are also usually found to have better machining properties, especially when the cuts are fine or light.

"Fine-grained steels" as compared with "coarse-grained steels" are, in general, found to have better surface conditions; greater impact strength and toughness; less distortion in treatment; less tendency to crack in trimming after forging, or during treatment or grinding; to be safer when heat-treating intricate or sharply filleted parts. In the carburizing grades they are adapted to a single quench, producing the finer-grained case and core, as shown by fracture.

It is generally conceded that in meeting the various conditions of processing and service, both grades of steel have their fields—neither being an all-purpose type of steel. When limited by a combination of restricted maximum limits of the hardening elements and maximum depth of hardness developed in heat treatment, there is no alternative but "coarse-grained steel." The "fine-grained steels," to meet the same depth of hardness requirements, must have a higher combination of hardening elements than "coarse-grained steels."

Note—Original papers were presented by H. W. McQuaid and E. W. Ehn, Trans. Am. Inst. Mining & Metallurgical Inst., Vol. LXVII. 1922 Trans. Am. Soc. for Steel Treating, Sept., 1922. Jl. Am. Iron & Steel Inst. V105, May, 1922.



AMERICAN SOCIETY FOR TESTING MATERIALS**STANDARD GRAIN SIZE CHART**

FOR

CLASSIFICATION OF STEELS¹**A. S. T. M. Designation: E19-33**

This chart is issued under the fixed designation E19; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1933.

Scope

1. This chart is intended to be used primarily for classification of S.A.E. and allied structural steels according to grain size which concerns only the size of the pearlitic grains and is independent of the condition of the excess carbide.

Treatment of Specimen

2. It is recommended that grain size studies be made only on specimens having prepared surfaces which are free from oxidation, decarburization, and influence of cold work.

The specimen shall be carburized at 1700° F. (927° C.) for not less than eight hours in a compound which will produce a hyper-eutectoid zone. Any of the highly energized compounds on the market will be satisfactory for this purpose. The specimen must be cooled slowly enough to produce a pearlitic structure. This is usually accomplished by furnace cooling. After cooling, a micro-section shall be prepared and the carburized zone examined at 100 diameters magnification and then compared with the grain size chart shown on pages 127-134 inclusive.

Grain Size Classification

3. (a) Sizes Nos. 1 to 5 may be considered "coarse-grained" steels and are generally characterized by complete carbide envelopes in the hypereutectoid zone.

¹ Under the standardization procedure of the Society, this chart is under the jurisdiction of the A. S. T. M. Committee E-4 on Metallography.

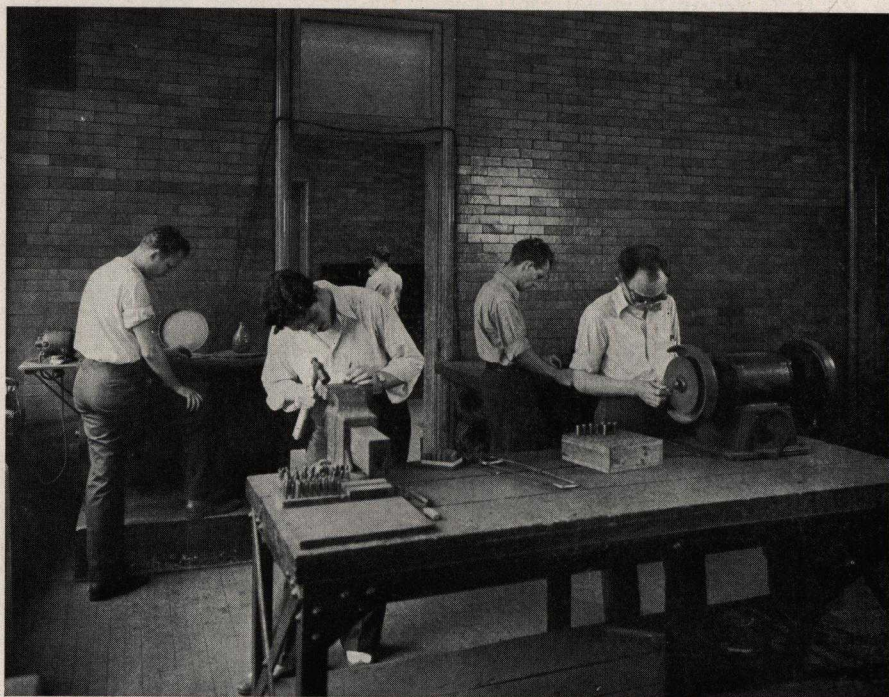
(b) Sizes Nos. 5 to 8 may be considered "fine-grained" steels and are generally characterized by incomplete carbide envelopes in the hypereutectoid zone.

(c) Size No. 5 may be considered as either a "coarse-grained" or "fine-grained" steel depending on whether those relatively few grains of the hypereutectoid zone which are outside of the No. 5 range are mostly coarser or finer than No. 5.

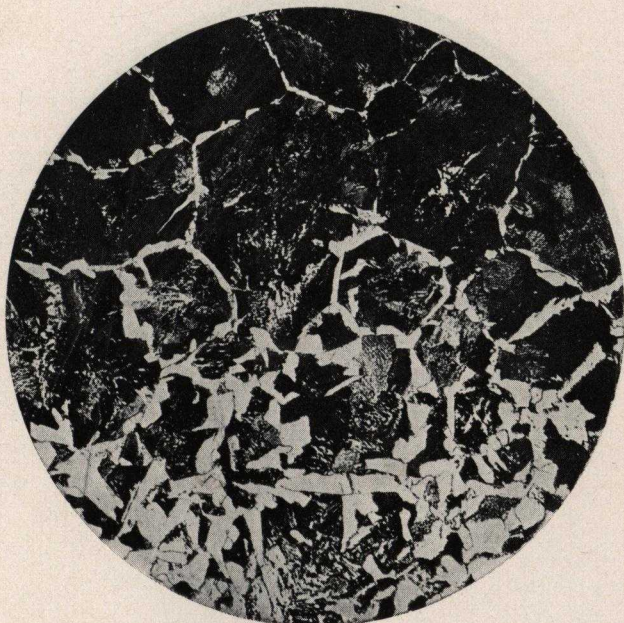
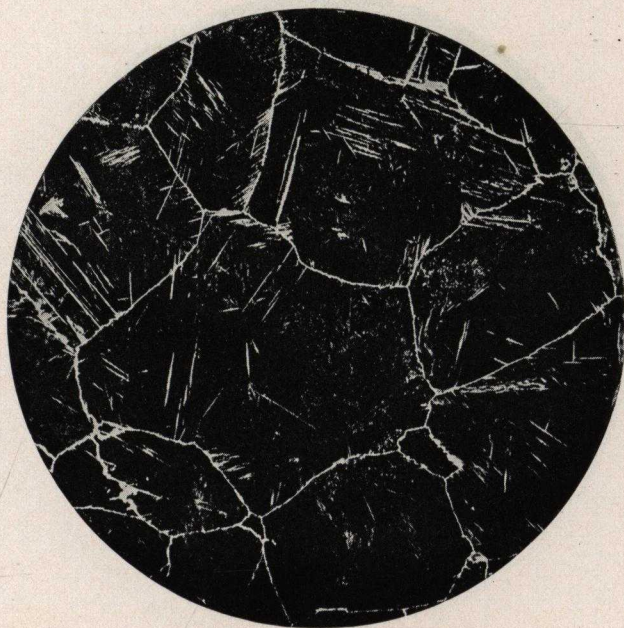
(d) The hypo-eutectoid zone is included as an aid in determining grain size. It also gives an indication of hardening characteristics. In the hypo-eutectoid zone, the condition of the ferrite will follow the same trend as the carbide in the hypereutectoid zone. Size No. 1 will usually show a maximum tendency for ferrite envelopes, while size No. 8 will usually show a maximum tendency for ferrite islands.

Note.—With the present state of the art of steel making, the size ranges Nos. 1 to 5 and Nos. 5 to 8 are suggested as standards for specifications.

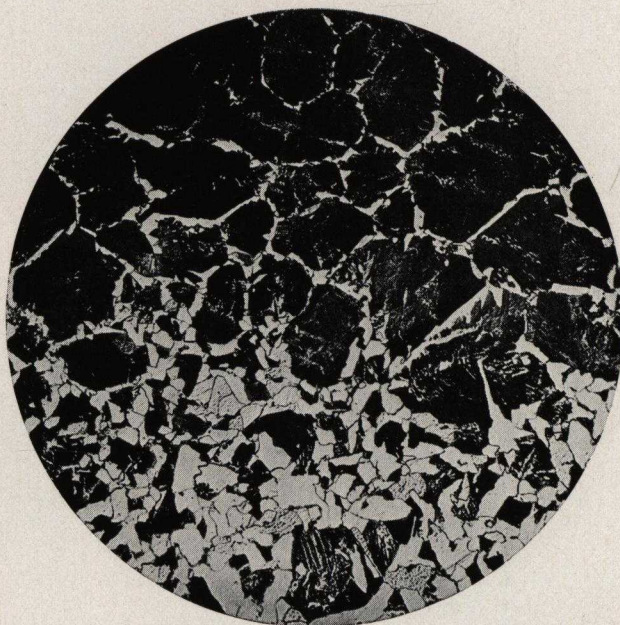
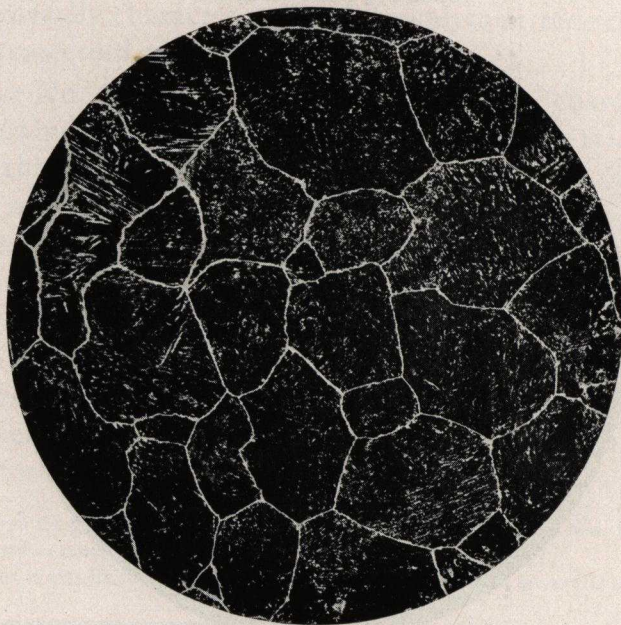
This scheme of classification is applicable to all S. A. E. and allied structural steels.



Metallographic Laboratory—Preparing specimens for examination

GRAIN SIZE CHART FOR CLASSIFICATION OF STEELSUp to $1\frac{1}{2}$ grains per sq. in.**No. 1**

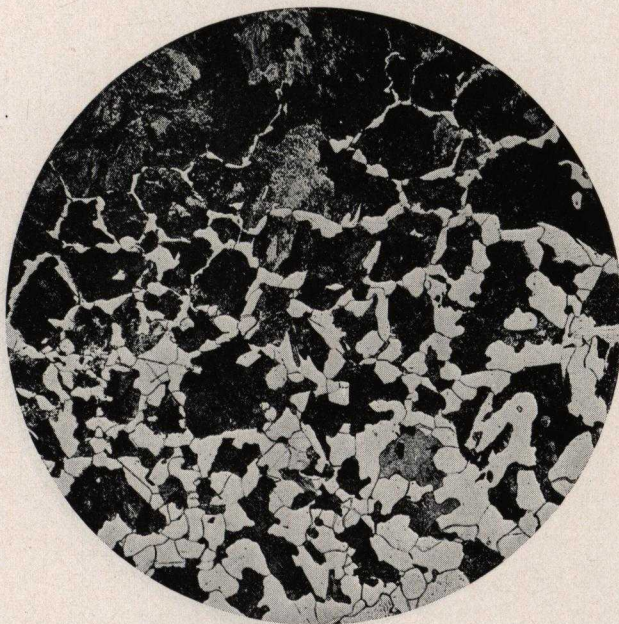
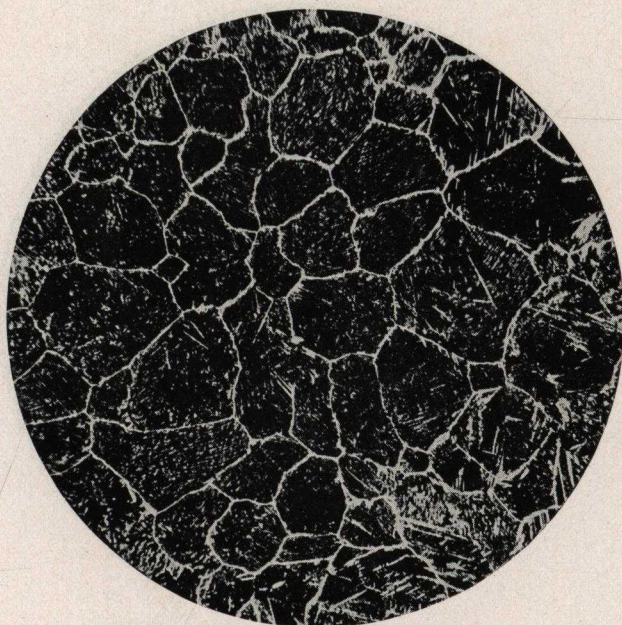
Samples carburized at 1700° F. (927° C.) for 8 hours (X 100). Upper and lower photomicrographs refer to hyper- and hypo-eutectoid zones, respectively, of the case.

GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS $1\frac{1}{2}$ to 3 grains per sq. in.**No. 2**

Samples carburized at 1700° F. (927° C.) for 8 hours (X 100). Upper and lower photomicrographs refer to hyper- and hypo-eutectoid zones, respectively, of the case.

GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS

3 to 6 grains per sq. in.

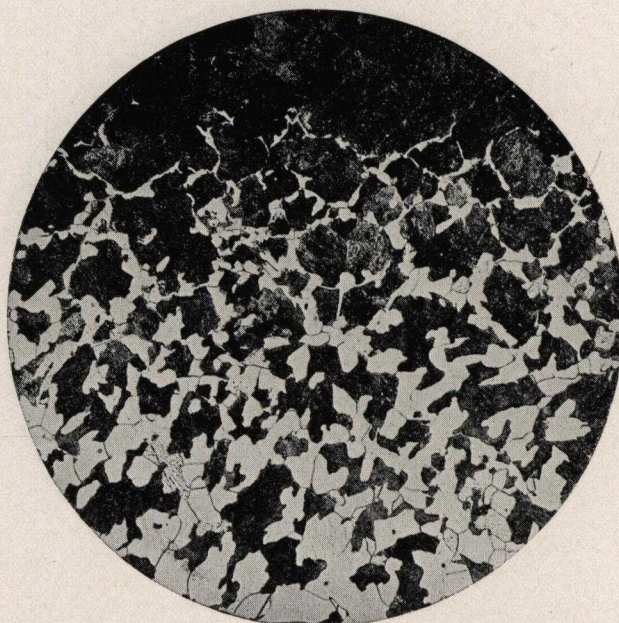
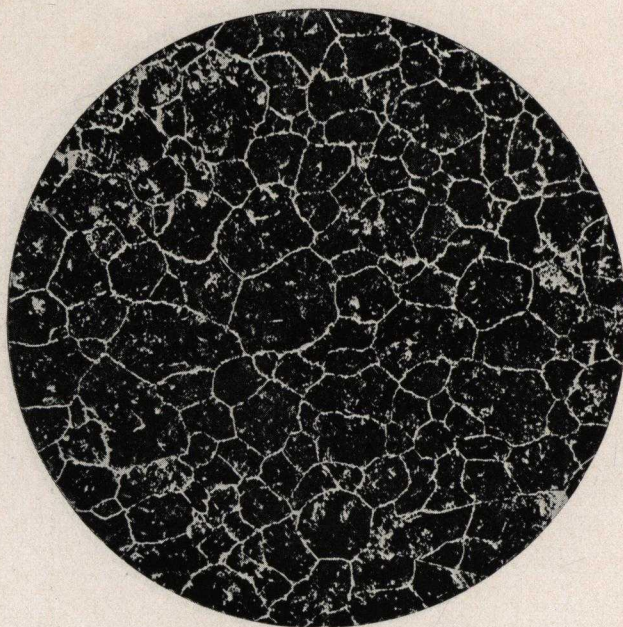
No. 3

Samples carburized at 1700° F. (927° C.) for 8 hours (X 100). Upper and lower photomicrographs refer to hyper- and hypo-eutectoid zones, respectively, of the case.

GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS

6 to 12 grains per sq. in.

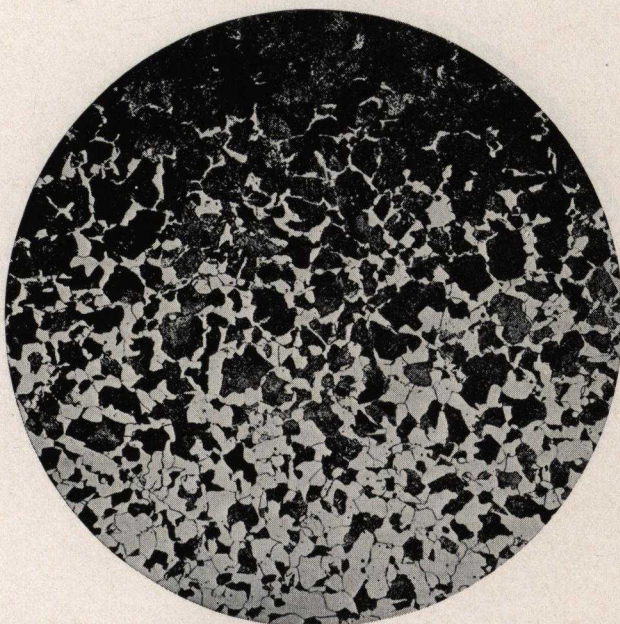
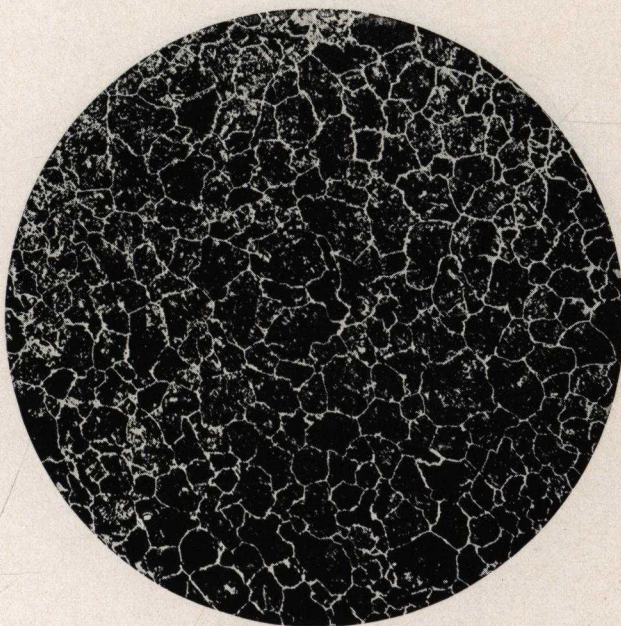
No. 4



Samples carburized at 1700° F. (927° C.) for 8 hours (X 100). Upper and lower photomicrographs refer to hyper- and hypo-eutectoid zones, respectively, of the case.

GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS

12 to 24 grains per sq. in.

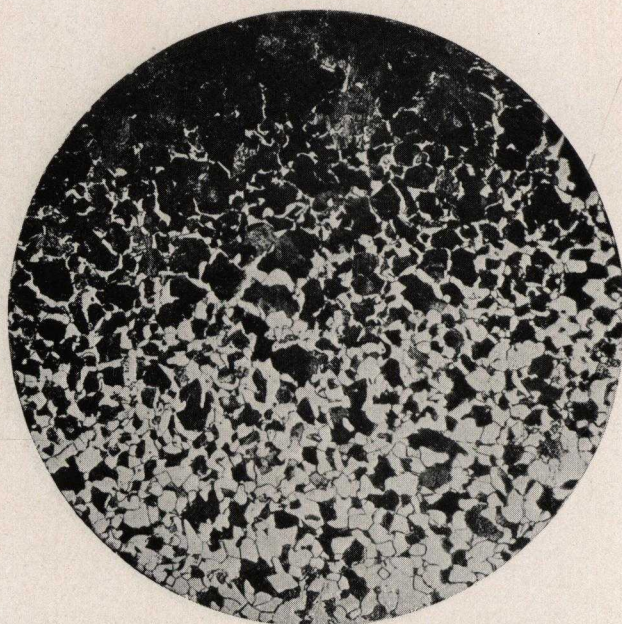
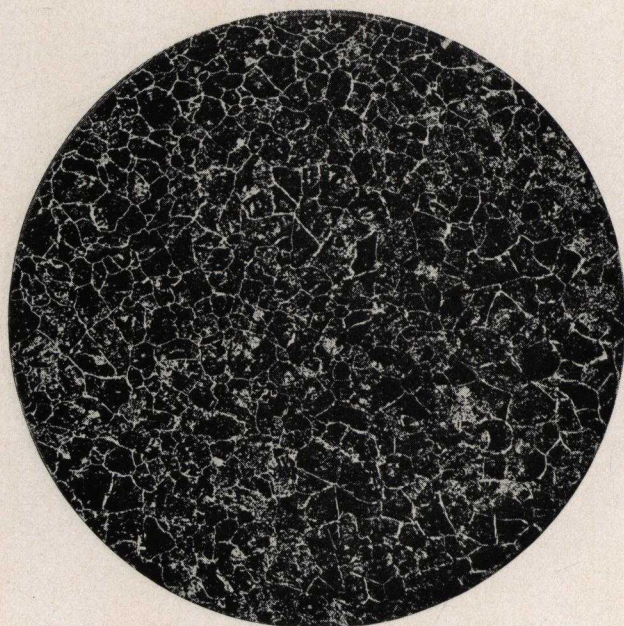
No. 5

Samples carburized at 1700° F. (927° C.) for 8 hours (X 100). Upper and lower photomicrographs refer to hyper- and hypo-eutectoid zones, respectively, of the case.

GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS

24 to 48 grains per sq. in.

No. 6

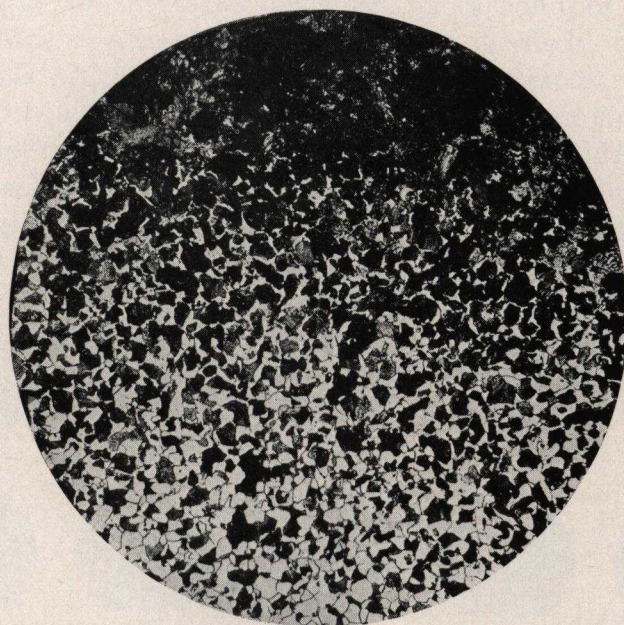
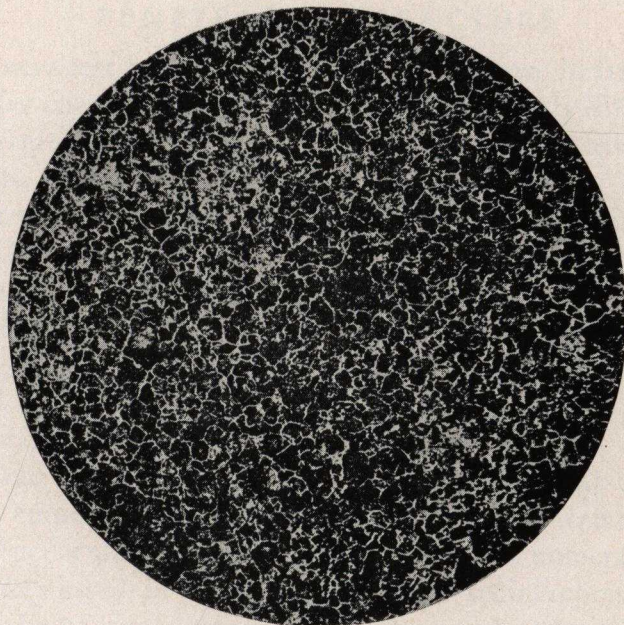


Samples carburized at 1700° F. (927° C.) for 8 hours (X 100). Upper and lower photomicrographs refer to hyper- and hypo-eutectoid zones, respectively, of the case.

GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS

48 to 96 grains per sq. in.

No. 7

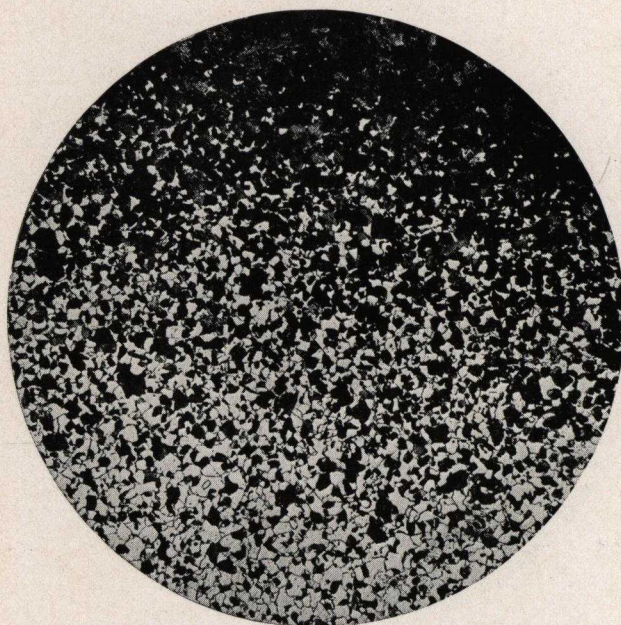
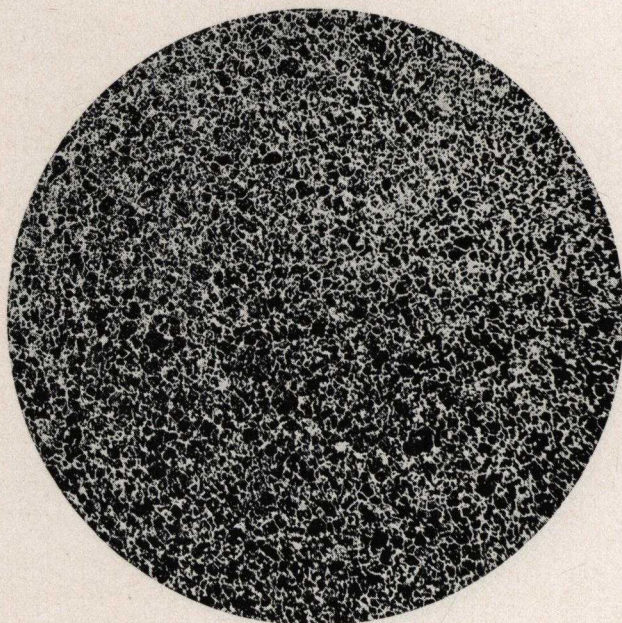


Samples carburized at 1700° F. (927° C.) for 8 hours (X 100). Upper and lower photomicrographs refer to hyper- and hypo-eutectoid zones, respectively, of the case.

GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS

96 grains and more per sq. in.

No. 8



Samples carburized at 1700° F. (927° C.) for 8 hours (X 100). Upper and lower photomicrographs refer to hyper- and hypo-eutectoid zones, respectively, of the case

THE P-F TEST

PENETRATION - FRACTURE

THIS new test has been developed to evaluate heats of steel of similar chemical analysis but which inherently differ in hardness penetration, quenching sensitivity, tendency toward grinding checks, toughness, fatigue resistance, etc.

This test gives results which parallel or compare directly with the A.S.T.M. (E19-33) carburizing test. The results can be directly applied to shop practice.

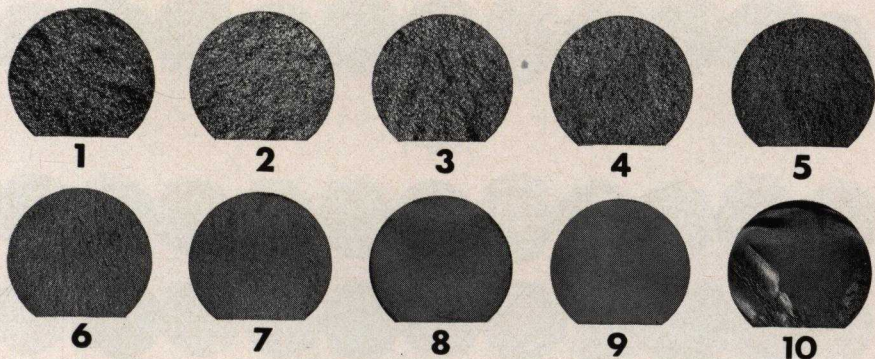
The test consists of determining changes in the penetration of hardness (P value) and the fracture grain size (F value) of samples quenched from normal and at temperatures arbitrarily set at higher intervals.

The fracture grain size is measured by a visual comparison with an empirical set of martensitic fracture standards. The hardness penetration used is recorded as the numerator of the fraction expressed in sixty-fourths of an inch, representing the depth of the hardened zone, measured on etched samples.

This test was originally developed for carbon tool steel but it can be made applicable, by a change of methods, to types of alloy steels which will subsequently be heat treated.

The Bethlehem organization has been in close contact with the development of this new test and has had considerable experience in the making of steels to meet definite P-F values, and the metallurgical organization is familiar with its application.

Note—See American Society for Metals Transactions—Paper presented by B. F. Shepherd—October 5th, 1934.



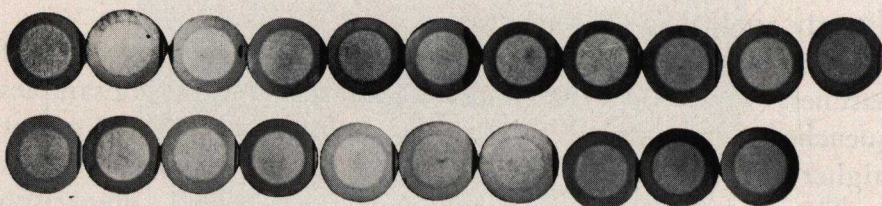
P-F fracture standards

P-F TESTS ON AN OPEN HEARTH HEAT OF STEEL

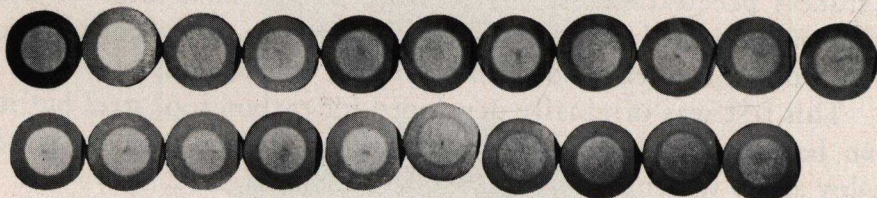
Each specimen is from a different ingot

PENETRATION

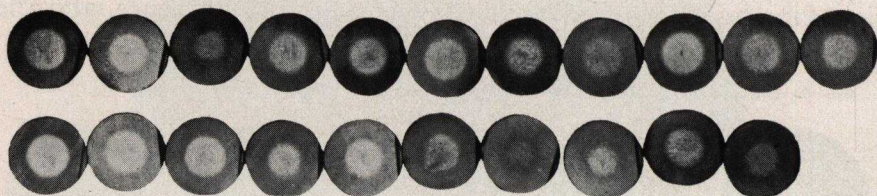
1450° F.



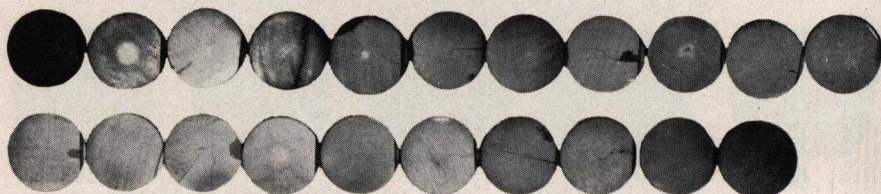
1500° F.



1550° F.



1600° F.

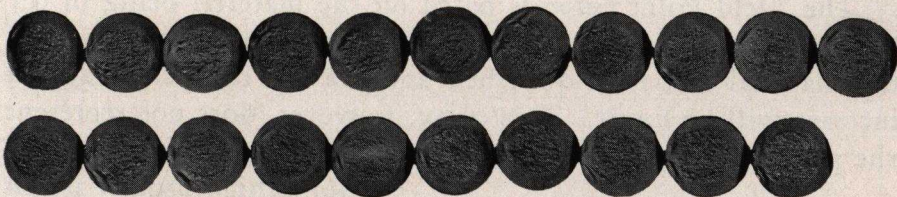


P-F TESTS ON AN OPEN HEARTH HEAT OF STEEL

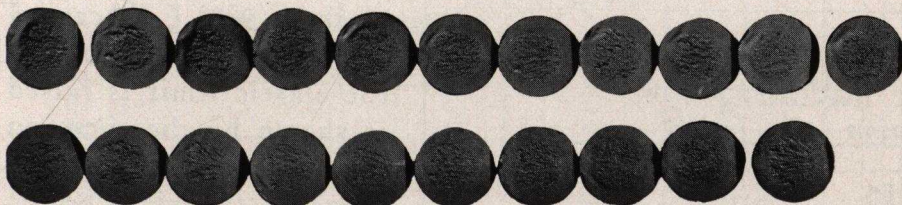
Each specimen is from a different ingot

FRACTURE

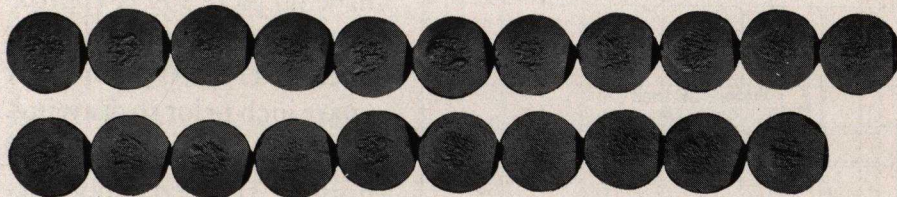
1450° F.



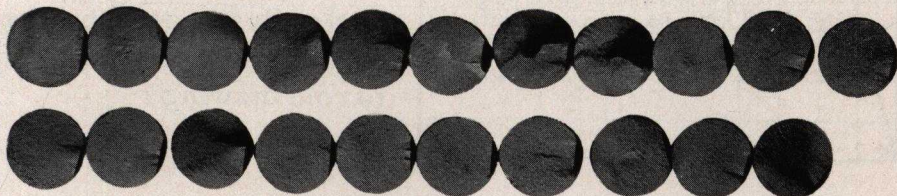
1500° F.



1550° F.



1600° F.



EFFECT OF COLD DRAWING ON TENSILE PROPERTIES OF ALLOY STEEL

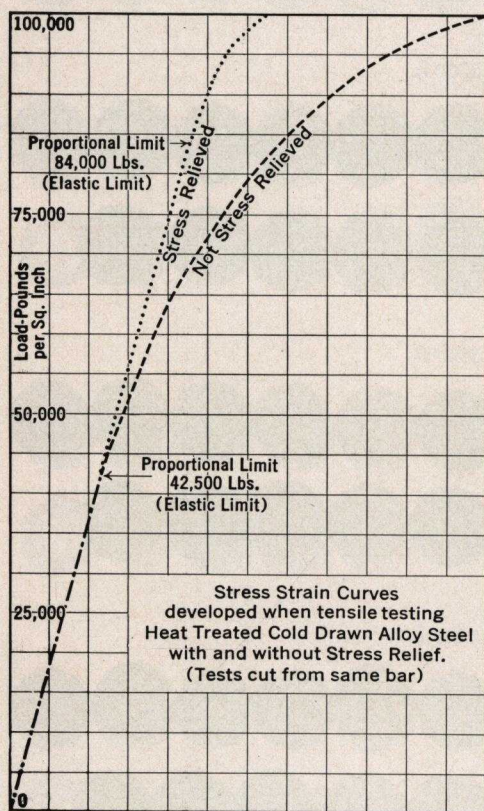
THE curve shown on page 139 indicates the approximate properties to be anticipated when cold drawing alloy steel bars up to 1 inch cross section and having 110,000 pounds per square inch tensile strength, or less.

The Yield Point curve is based on the material being in the "as-rolled" or "annealed" condition prior to cold drawing. If the material has been quenched and drawn, the percentage of increase will be lower. This curve, however, does not represent the percentage increase in Elastic Limit in the "as drawn" condition which usually is not

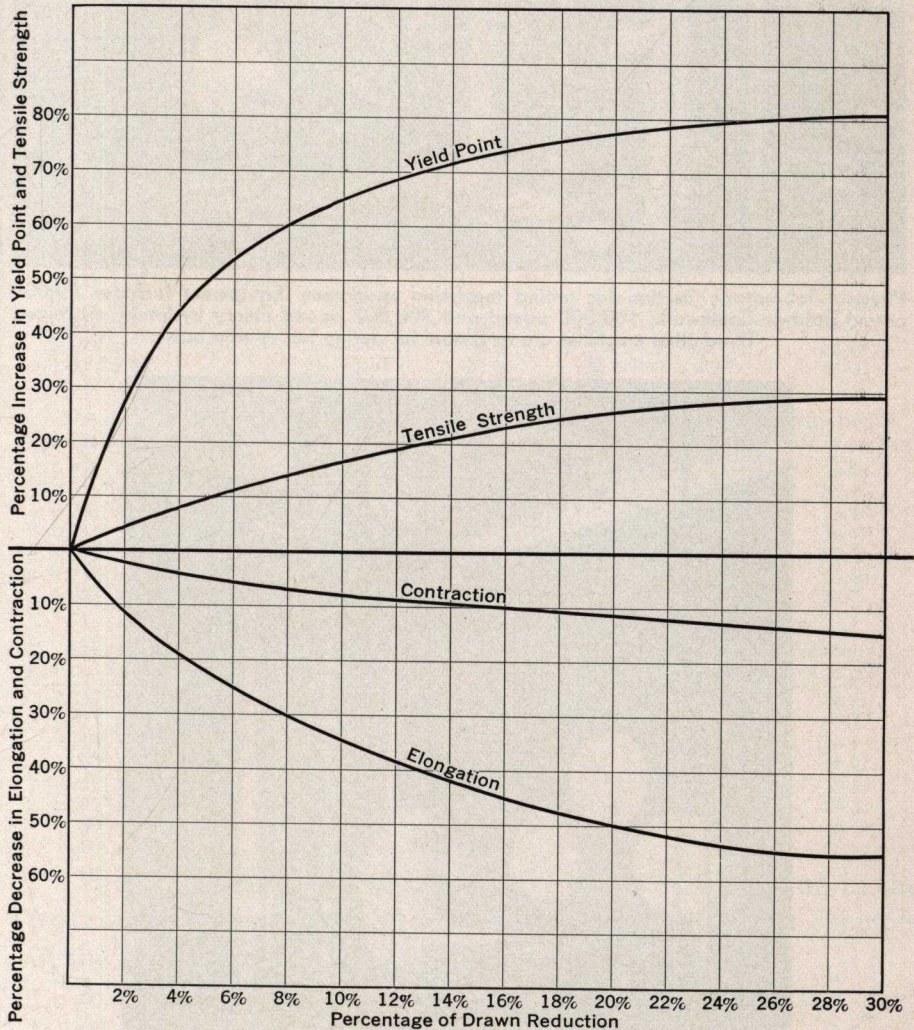
increased by the operation unless a stress relief anneal of about 900° F. is carried out. With this low anneal the elastic limit is raised as shown by the curve on this page and closely approaches the yield point.

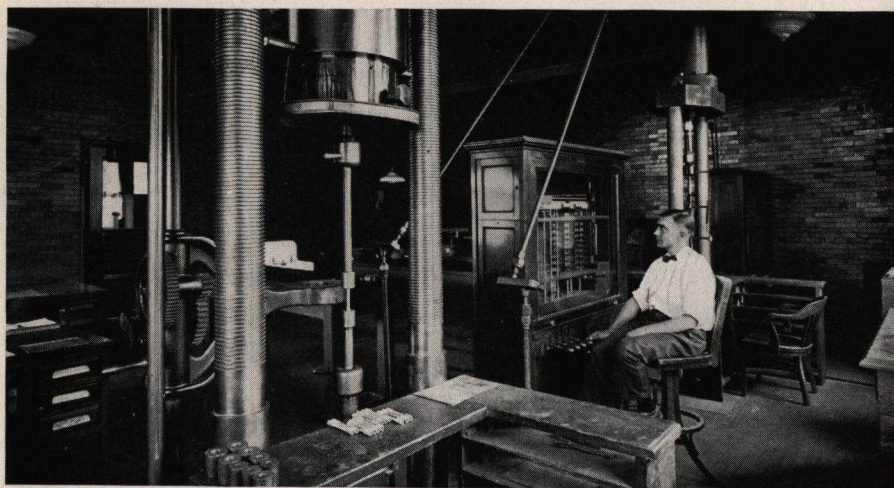
The tensile strength curve on page 139 is approximately accurate provided it is below 110,000 pounds per square inch prior to drawing.

The curves on page 139 showing the percentage decrease in elongation and reduction of area are not materially changed by the condition of the steel prior to cold drawing.

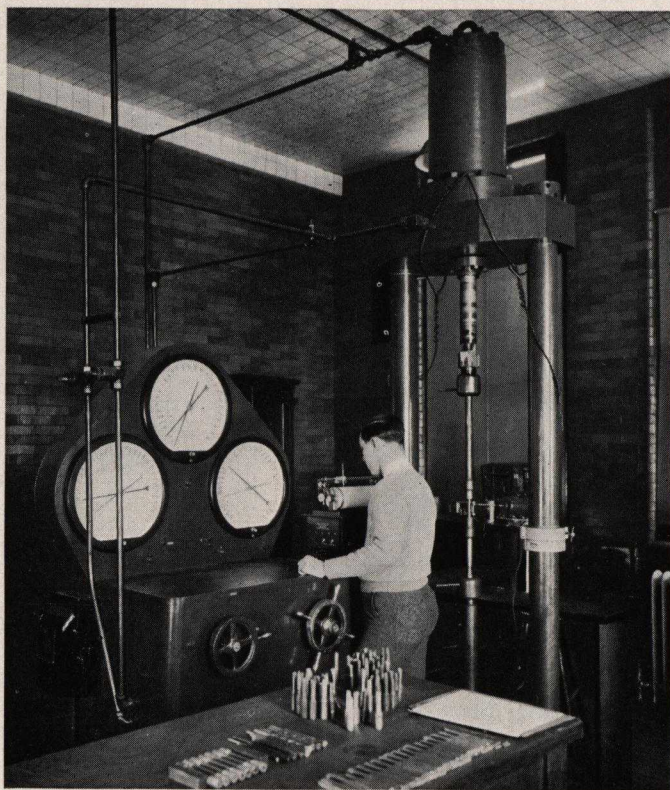


EFFECT OF COLD DRAWING ON TENSILE PROPERTIES OF ALLOY STEEL





Physical laboratory. Section for testing machined specimens. Equipment includes 60,000 pound Baldwin-Southwark, 100,000 pound and 300,000 pound Emery hydraulic machines. Three other machines are available for testing full section bars



Baldwin-Southwark tensile testing machine

EFFECT OF SIZE OF TEST BAR IN TENSILE TESTING

THE effective diameter and length of a tensile test bar causes no serious trouble in determining the strength of the steel as indicated by the tensile strength, yield point, or elastic limit values, or the reduction of area. They do, however, have a marked effect on the percentage of elongation values obtained, as shown below:

Size of Reduced Section	0.25 Carbon Steel Annealed Elongation in per cent measured over					Reduction of Area in per cent
	1"	2"	4"	6"	8"	
0.252" x 2"	42.0	32.5				66.98
0.505" x 2"	52.0	38.0				61.33
0.750" x 2"	59.0	41.0				61.05
1.000" x 2"	68.0	48.0				67.75
0.252" x 8"		28.0	21.7	19.1	17.6	66.08
0.505" x 8"		36.0	29.0	26.6	24.5	62.79
0.750" x 8"		45.0	34.5	30.6	27.5	61.39
1.000" x 8"		55.0	37.0	32.2	29.2	64.00

Size of Reduced Section	0.30 Carbon—3½% Nickel Steel Annealed Elongation in per cent measured over					Reduction of Area in per cent
	1"	2"	4"	6"	8"	
0.252" x 2"	31.0	24.5				59.84
0.505" x 2"	40.0	29.0				55.46
0.750" x 2"	47.0	31.5				55.56
0.252" x 8"		21.0	16.7	15.7	14.7	54.67
0.505" x 8"		31.5	23.0	20.0	18.5	57.3
0.750" x 8"		36.0	26.0	22.7	20.5	55.56
1.000" x 8"		42.0	31.0	26.3	23.5	54.7

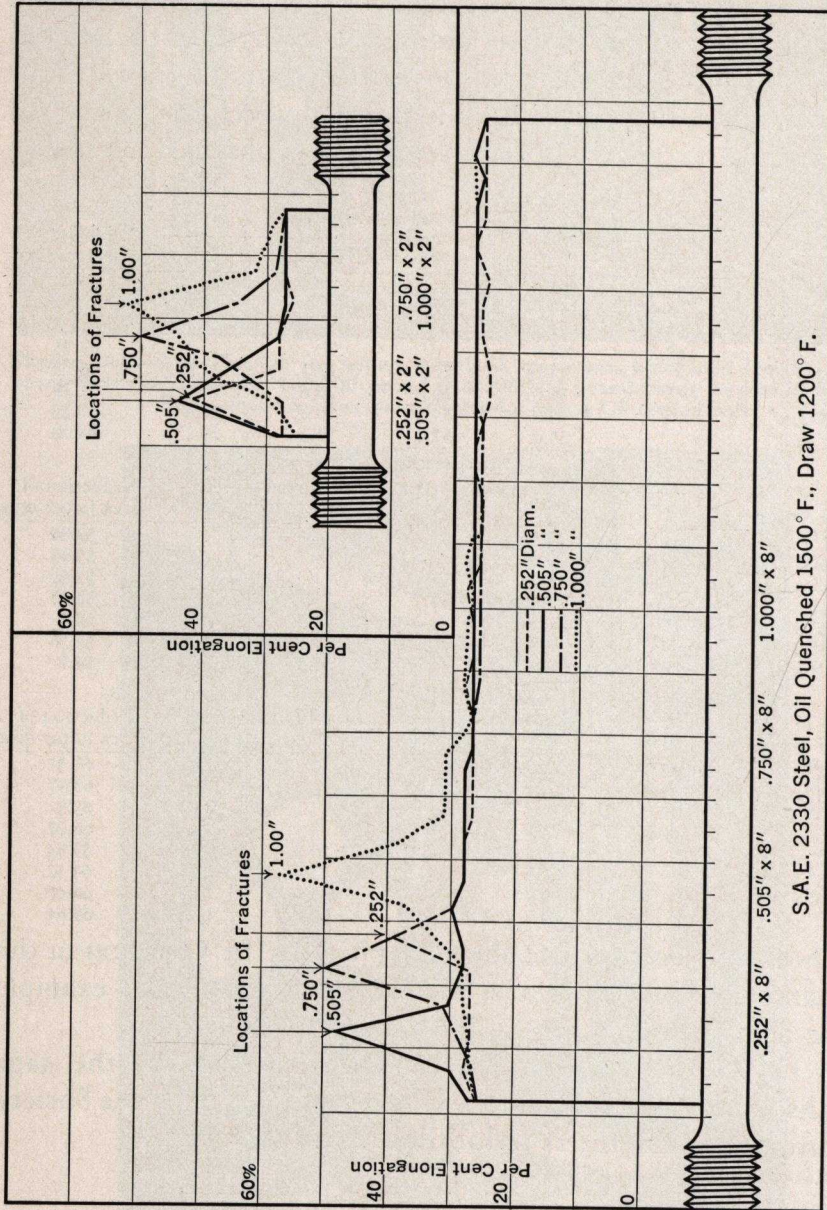
Size of Reduced Section	0.30 Carbon—3½% Nickel Steel, Oil Quenched—Drawn 1200° F. Elongation in per cent measured over					Reduction of Area in per cent
	1"	2"	4"	6"	8"	
0.252" x 2"	25.0	17.0				62.31
0.505" x 2"	36.0	23.0				63.97
0.750" x 2"	49.0	30.0				65.9
1.000" x 2"	60.0	37.0				66.02
0.252" x 8"		18.5	13.5	10.8	9.63	59.84
0.505" x 8"		24.0	17.0	13.0	11.4	64.52
0.750" x 8"		31.0	19.5	15.0	12.7	66.68
1.000" x 8"		38.0	23.5	18.0	14.75	68.64

The curves on page 142 show graphically the variation in the percentage of elongation over the bar length of the last example in the above tables.

A list of the diameters of the gage lengths, and the gage lengths, of machined round tensile test bars is given by the Society of Automotive Engineers as follows:

Size Bar	Diameter Gage Length	Gage Length
Over ¾" (Standard)	0.505"	2.0"
½" to ¾"	0.375"	1.5"
⅜" to ½"	0.250"	1.0"
¼" to ⅜"	0.125"	0.5"

EFFECT OF GAGE LENGTH OF TEST BAR IN TENSILE TESTING



Graphs showing percentage of elongation throughout the length of test bars. Calculated from elongation of $\frac{1}{4}$ -inch increments.

EFFECT OF MASS ON PROPERTIES OF HEAT-TREATED STEEL

AS THE size of a part subjected to heat treatment increases, the effectiveness of the cooling operation decreases. To overcome this, it is customary to increase the quenching temperature somewhat as size increases. However, this change does not balance the loss in properties shown by test bars taken at the midway location or along the central axis of large parts.

This is noticed in either the strength as measured by the elastic limit, yield point and tensile strength; or in the ductility as recorded by the elongation and reduction of area. Which of these is affected depends quite naturally on the drawing temperature.

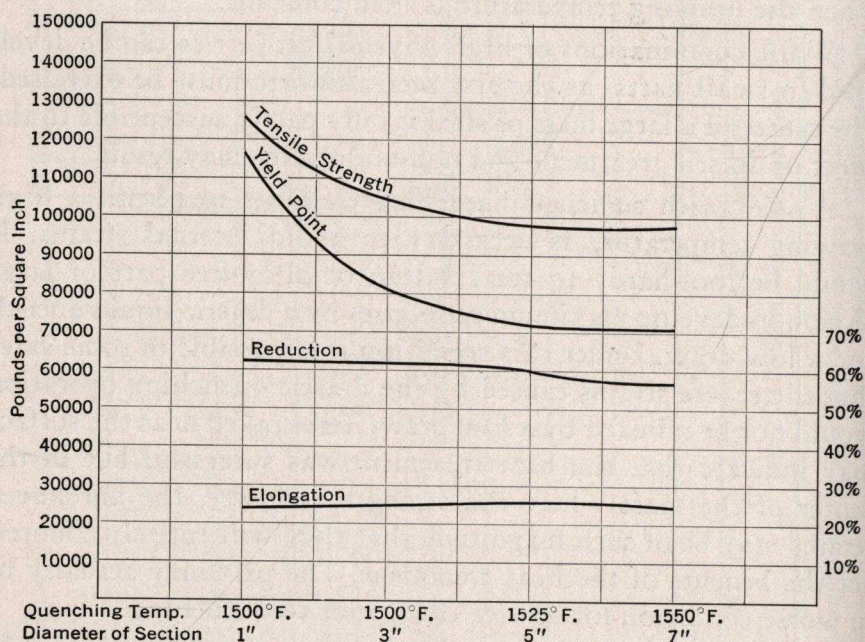
The following curve of an alloy steel, shows these changes when the drawing temperature is held constant.

While combinations of high physical properties can be developed in small parts, as the size increases care must be exercised. The center of a large mass of steel is only partly susceptible to the effect of drastic treatment and non-uniformity may result.

A steel with sufficient hardening elements to permit a high drawing temperature is necessary to avoid internal strains. It would be fool-hardy to treat a lean or alloy-free part of large section to develop maximum properties by a drastic liquid quench and a low draw. Under this condition it is possible in some cases that the severe strains caused by the drastic quenching operation would not be relieved by a low draw. Tests taken near the surface may indicate that the heat treatment was successful but in the center of the mass where the strength is lower, the unrelieved strains may be of such magnitude that they will entirely counteract the benefits of the heat treatment. The part may actually be in worse condition for service than prior to quenching.

The purpose of this warning is not to condemn liquid quenching as an unsuitable method for heat treatment but rather to urge discretion in its application and care in selection of the steel.

There are specifications for very large parts, whose size is beyond the scope covered by this book, which forbid liquid quenching because of the danger of unrelieved stresses and non-uniformity. These large parts are highly stressed in dynamic service and the best material, when mass is considered, is one having a composition which is capable of developing good physical properties without drastic treatment. A very large-section part, when properly treated by a combination normalizing and annealing, will have the best characteristics for service. While the physical properties as demonstrated by tensile tests may be disappointingly low when compared with the highest values obtained for the same composition treated and tested in small sections, the actual factor of safety will be higher than would be the case were the heavy part drastically treated for higher physical properties.



4645 Steel. Normalized 1650° F., oil quenched, drawn at 1200° F. 0.40 to 0.50 C., 0.50 to 0.80 M., 0.040 P. max., 0.050 S. max., 0.15 to 0.30 Si., 1.65 to 2.00 Ni., 0.20 to 0.30 Mo.

ENDURANCE STRENGTH OF STEEL

IT HAS been found in laboratory tests for endurance or fatigue that the only property of steel, usually measured, which bears any relation to the endurance strength, is tensile strength. The general relation is shown on the curve. In service, other factors enter which usually are not duplicated in the laboratory. The laboratory tests, therefore, show the values obtained only under ideal conditions, which in practical application may be misleading.

These tests are always carried out on a carefully machined specimen, polished to obliterate even microscopic scratches as far as possible, otherwise the results would be erratic and misleading. The test bar further is either very gently tapered or curved so that no localized concentration of stresses can be set up while the test is being performed. The tests are run dry, for if water, acid, or in some cases gases, were present, they would exert an oxidizing or corrosive effect on the test bar, and the results obtained would be appreciably poorer.

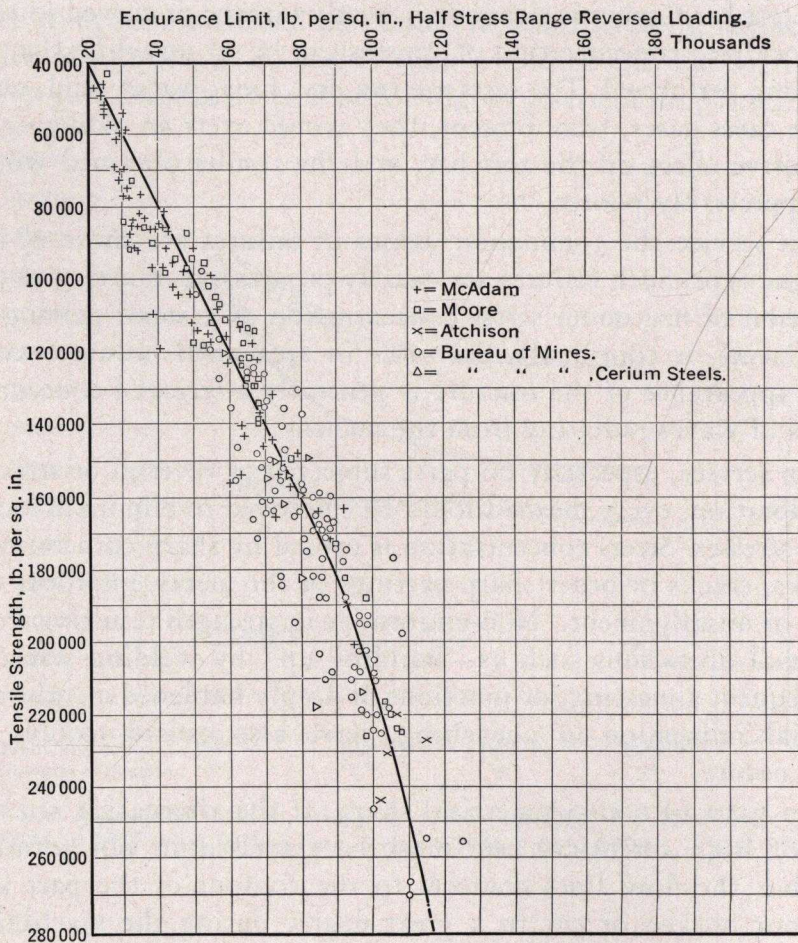
In service the commonest causes of failures are those of the fatigue type. Such failures are usually progressive. Starting at the location of maximum stress concentration as a small parting of the metal, it continually increases in area until failure occurs. The appearance of the fracture is generally a series of concentric rings of waves radiating from the nucleus.

In service, especially on parts subjected to reversal of stresses or vibration, every means should be employed to eliminate localized stresses. Stress concentration is caused by sharp corners, tool marks, cracks or other sharp partings of the metal, improper design or misalignment. Non-uniformity in strength resulting from thermal operations such as "building up" by welding without subsequent annealing, or junctions of deeply hardened metal from partial immersion in quenching, have also caused trouble of this nature.

In parts of non-symmetrical shape, if the alternating stresses are of high intensity, care must be exercised in hot forming so that the flow lines conform to the contour of the part and are not broken or cut to a great degree during the machining

operation. As an example, the flow lines of a billet are all longitudinal to the axis. A crankshaft for a modern airplane engine machined directly from a billet would be doomed to early failure of the fatigue type due to the fact that the flow lines would run across the "throws" rather than follow the contour of the shaft.

In some cases a cure for fatigue failure can be found by using a different grade of steel, or proper treatment, or improved metallurgical refinement. If the proper steel with satisfactory refinement has been used and the cause is mechanical, it must be remedied mechanically by locating the cause and making the proper changes or corrections in design or assembly.



DEFLECTION OF STEEL UNDER STRESS

(MODULUS OF ELASTICITY)

UP TO their elastic limits, all steels regardless of composition, treatment, hardness or other properties will, with a given section and under the same conditions, temporarily deform practically the same amount under the same load. The modulus of elasticity, nearly the same for all steels, controls this phenomenon.

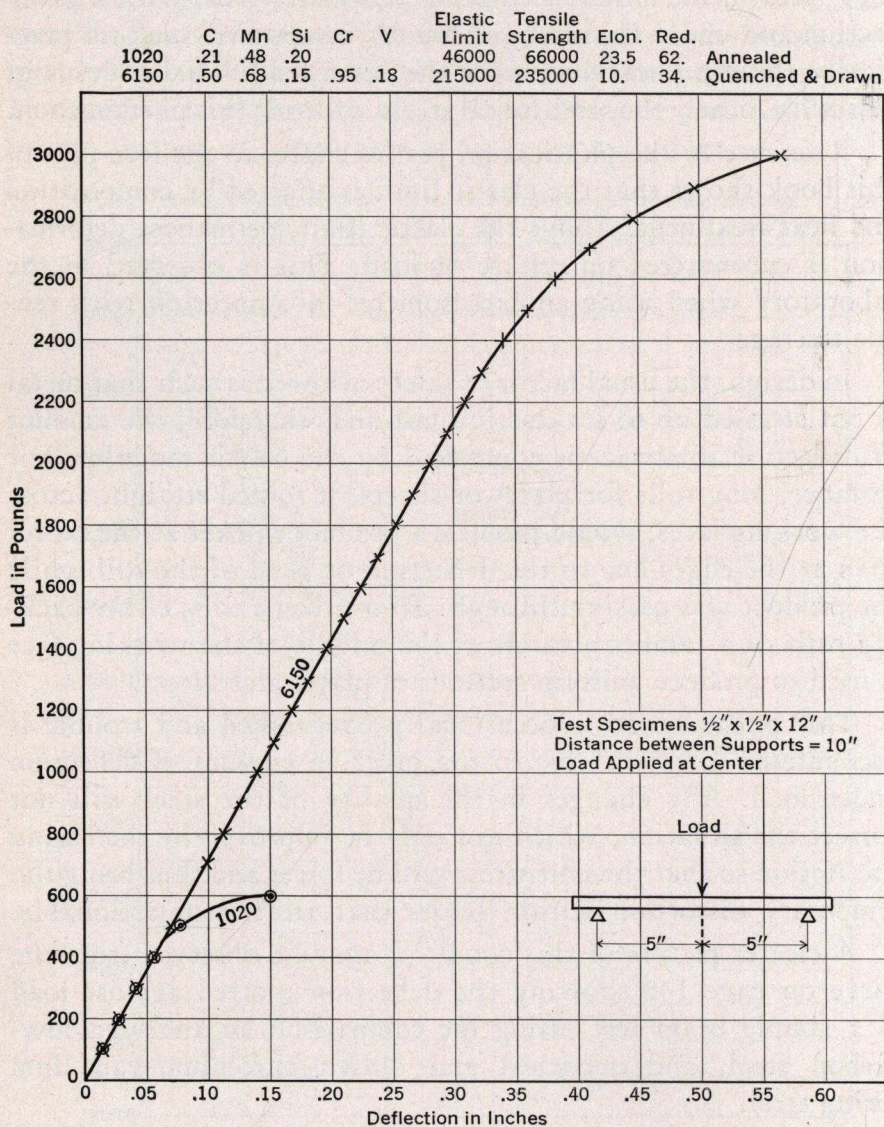
Reference to the physical properties charts in the fore part of this book shows that the elastic limit is affected by composition and heat treatment. Above the elastic limit, permanent deformation is encountered on release of load. This is observed in the laboratory when using an extensometer in connection with tensile testing.

In design, the usual factor of safety allowed is such that metal is not stressed up to its elastic limit and, therefore, the amount of deflection in service is controlled by the elastic modulus. For instance, long rolls for plates or sheets, if turned straight across the working faces, would produce a product thicker at the center than at the edges due to the deflection or bend of the roll while the product was passing through. To overcome this, either backing rolls or a camber greatest at the middle of the working face is used to produce uniform sections of plates and sheets.

This phenomenon is occasionally overlooked and trouble is encountered in service due to too great an amount of deflection under load. Any changes in the quality of the steel will not correct the situation, which can only be improved by increasing the section so that the unit stress will be lower and thus bring the temporary distortion within limits that are not objectionable.

A clearer picture of this condition may be observed from the curve on page 148 showing the deflection plotted against load in a simple beam test, using for comparison an annealed low-carbon steel, and quenched and drawn chromium-vanadium spring steel.

DEFLECTION OF STEEL UNDER STRESS

DEFLECTION CURVE OF ANNEALED 1020
and QUENCHED and DRAWN 6150 STEELS

STEEL AT LOW TEMPERATURES

THE effect of low temperature on the properties of steel has been the subject of a number of investigations. Experiments have been carried out over a range of temperatures down to and including the boiling point of liquid air (-310°F.). Alloy steels of the types described in this publication all exhibit the same general tendencies with respect to change in any particular property with descending temperature.

A summation of the laboratory tests shows, with decreasing temperatures, a progressive increase in yield point, tensile strength, hardness, endurance limit, modulus of elasticity, thermal and electrical conductivity; and decreases in elongation, reduction of area, impact resistance, compressibility, thermal expansion and specific heat.

The most serious effect of low temperature is the loss of impact strength; however, laboratory tests indicate that the drop in impact values is not as great in unnotched bars as in notched bars which are generally used in testing steel for this property. In practical terms this might be interpreted as indicating that with decreasing temperatures steel progressively loses its power of resisting suddenly applied localized stresses.

A comparison of a few tensile tests will clearly show how the properties of steel change with temperature.

Steel Treatment	Room Temperature				Boiling Pt. Liquid Air (-310°F.)			
	Y. P.	T. S.	El.	Red.	Y. P.	T. S.	El.	Red.
1045—1500° Annealed	50000	89000	29	48	128000	138000	3.8	3.6
1045—1500° Oil Quenched								
1000° Drawn	77000	104000	25	67	150000	160000	9.8	9.4
3240—1450° Annealed	75000	117000	24.5	62	132000	172000	14.3	13.1
3240—1450° Oil Quenched								
1150° Drawn	116000	132000	21	60	169000	187500	19	30

The following figures show the impact strength of a few representative steels at low temperatures in the annealed condition. Tests were made on a Charpy machine with keyhole notched specimens.

Analysis					Impact Values at				
C.	Mn.	Ni.	Cr.	Mo.	60°F.	0°F.	-100°F.	-200°F.	-310°F.
0.32	0.44	...	...	...	20	7½	21½	1	¼
0.10	0.45	3.4	...	...	57½	57½	43½	17	1
0.10	0.34	5.1	...	...	41	38	22½	8	2
0.12	0.45	3.6	...	0.27	51	51	36	14	1½
0.30	0.54	3.5	0.93	0.27	29	29½	16	8	3

Reprinted from International Nickel Company, Data book, "Nickel Alloy Steels."

Generally speaking, quenching and drawing at a temperature above 1050° F. improves the impact resistance of steels at low temperatures. The following tests have been reported by an authority using a special shaped "V" notched Charpy bar, so that the results are not directly comparable with those given above:

S.A.E. Steel		Treatment	Impact Values at				
			55° F.	-31° F.	-76° F.	-166° F.	-310° F.
2335	1525° Oil—1150° Drawn		114	54	59	29	7
2335	1525° Annealed		30	17	12	4	2
3435	1525° Oil—1150° Drawn		87	77	76	45	23
3435	1525° Annealed		68	35	20	25	4

It must be recognized that it is impossible to carry out laboratory tests that entirely simulate conditions or combinations of conditions that occur in service. For instance, wheel burns on rails caused by stalled locomotives in extremely cold weather may result in fine checks and localized hardening of the surface of the rail head. Here we have a combination of heating, overloading, and quenching due to the cold mass of the rail not locally affected.

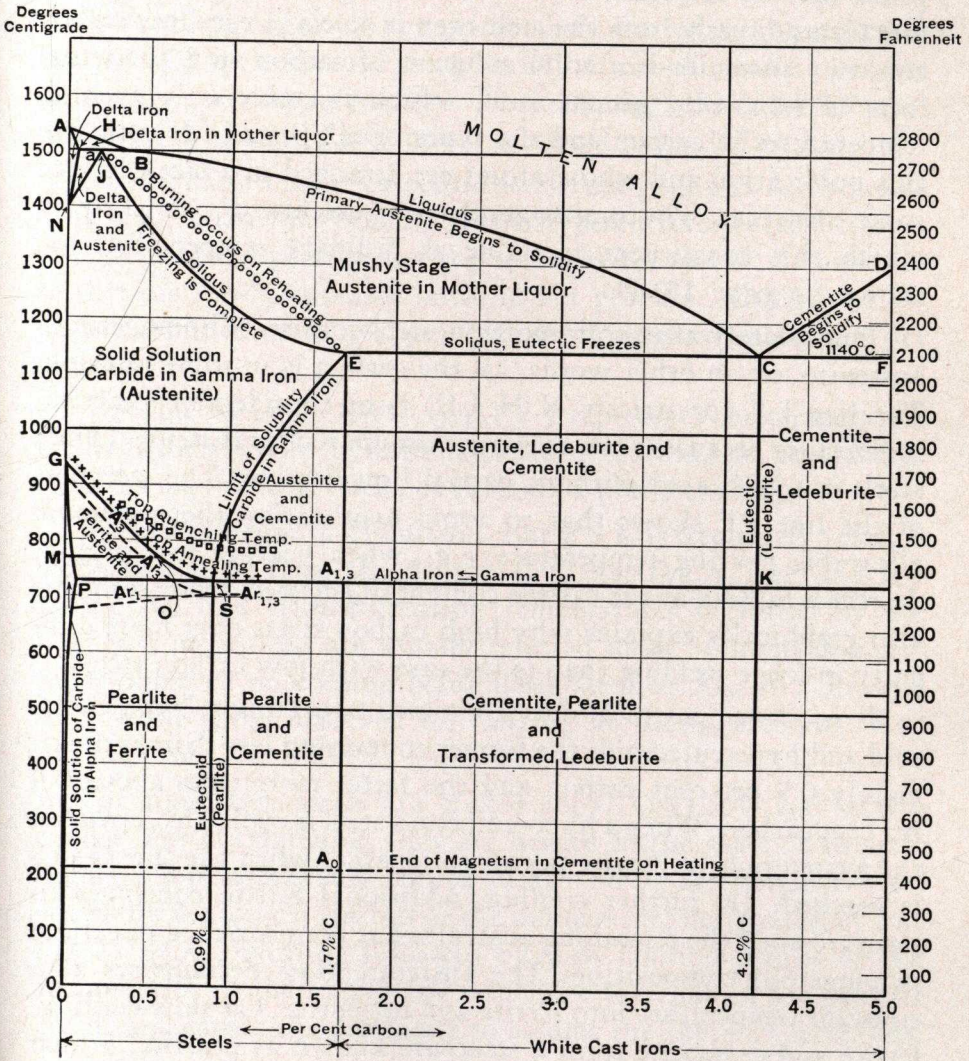
In general, for a given chemical analysis, fine-grained steels (A.S.T.M. E19-33 Test) are more resistant to impact at low temperatures than coarse-grained steels.

Welding or local heating for bending of the higher carbon content steels, unless followed by treatment, may have a direct detrimental influence on impact strength at low temperatures.

Alloy steels in the ferritic condition have been used with considerable success in service down to -50°F. Below this temperature their usefulness decreases (unless the part is quenched and drawn, in which case somewhat lower temperatures may be withstood) and it is recommended that steel of the austenitic type such as low carbon, 18 per cent chromium and 8 per cent nickel, or steels with richer combinations of alloying elements be substituted. The rich alloy austenitic steels have been found to be reliable at all low temperatures where steel has been used up to the present time.

THE IRON-CARBON DIAGRAM AND ITS APPLICATION

THE iron-carbon, or more correctly the iron cementite equilibrium diagram is based on slowly heated or cooled carbon steels. Those solutions designated as steels fall within the field containing less than 1.7 per cent carbon. When liquid steel is



cooled to a temperature that falls on the line A B C, a solid phase begins to appear as crystallites and the amount of solidus increases as the temperature is lowered until finally all liquid has disappeared. In steels containing less than about 0.55 per cent carbon the delta phase is formed directly from the melt, but, as all of the delta phase transforms to the gamma phase or austenite on passing through the line N J, for most purposes, the delta phase may be disregarded and the assumption made that austenite forms directly from the melt even in steels of very low carbon content. Austenite is a solid solution of carbon in a particular form of iron, i.e., gamma iron, which is stable only at high temperatures in carbon and the types of alloy steels discussed in this publication and whose atoms are arranged in a face-centered cubic structure. Photomicrographs of austenite in an alloy in which this constituent is stable at ordinary temperatures are shown on page 153-D.

Immediately after solidification, steel consists of homogeneous austenite, or, in other words, all the carbon is in solid solution. The line J E (or strictly N H J E) is of considerable practical importance because it represents maximum temperatures to which steels can be heated without partial liquefaction. The steepness of the line J E shows that to avoid overheating the maximum allowable heating temperature, e.g., when heating for forging, decreases rapidly as the carbon content of the steel increases. This also graphically explains why high carbon steels offer more difficulty in forge welding than is the case with low carbon steels.

It is convenient to divide steels into two groups, hypo-eutectoid and hypereutectoid; the former containing less than approximately 0.9 per cent carbon and the latter more than about 0.9 per cent carbon. When a hypo-eutectoid steel is cooled from within the austenite field, ferrite begins to separate when the line G O S is reached. On further cooling, additional ferrite continues to separate until the remaining austenite has been enriched in carbon to eutectoid composition. The austenite then decomposes at a constant temperature into ferrite and cementite. On slow cooling, ferrite and cementite form a structure known as pearlite, which

consists of alternate platelets of ferrite and cementite and shows as the typical thumb print pattern in micrographs. Appearance of pearlite is illustrated on page 153-B. The ferrite is merely the form of iron stable at low temperatures, body-centered cubic crystals, and contains almost no carbon in solution. Cementite is the compound Fe_3C .

When hypereutectoid steels are cooled from the austenite field, cementite begins to separate when the line E S is reached and on further cooling continues to separate until the remaining austenite has reached the eutectoid composition, after which the austenite decomposes and forms pearlite. Photomicrographs of hypereutectoid steel thus cooled are shown at top of pages 127 to 134.

Slowly cooled hypo-eutectoid steels, see page 153-A, therefore consist of ferrite and pearlite while hypereutectoid steels consist of cementite and pearlite, see top of pages 127 to 134. A eutectoid steel, page 153-B, contains nothing but pearlite, which is an intimate mixture of ferrite and cementite, approximately 0.9 per cent carbon.

The line M O, at 768°C . (1414°F .) represents the temperature below which ferrite is ferromagnetic. According to the present conceptions this line does not indicate a phase change.

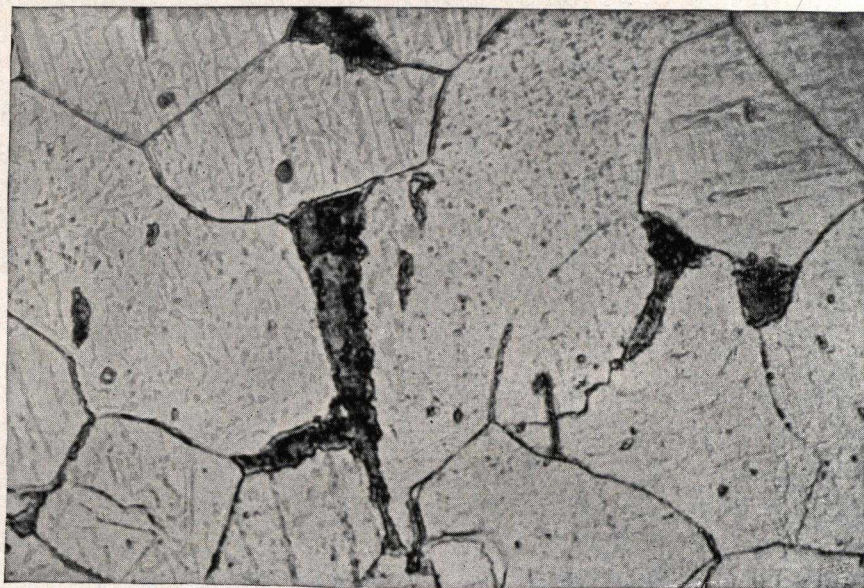
For convenience in discussion, line P S K is frequently referred to as A_1 line, M O as the A_2 line, G O S as the A_3 line, and E S as the A_{cm} line. Transformation temperatures indicated by the lines just mentioned are usually referred to as "critical points," those observed on cooling being designated as Ar_3 , Ar_2 , Ar_1 and Ar_{cm} , while those observed on heating are designated Ac_1 , Ac_2 , Ac_3 and Ac_{cm} .

For annealing, steels are heated above G O S K and slowly cooled. For normalizing, they are heated to the same or slightly higher temperatures and cooled in air. Steels are frequently annealed for prolonged periods at the temperature designated by line P S K. Such annealing followed by slow cooling breaks up the arrangement of the ferrite and cementite platelets in the pearlite grains and causes the cementite to assume the shape of spheroids,

FERRITE IN HYPO-EUTECTOID STEEL

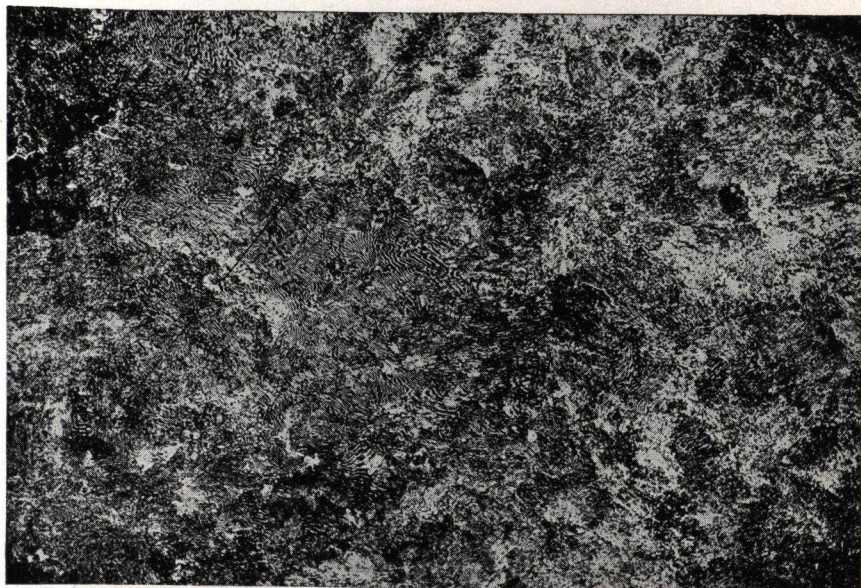


100 magnifications

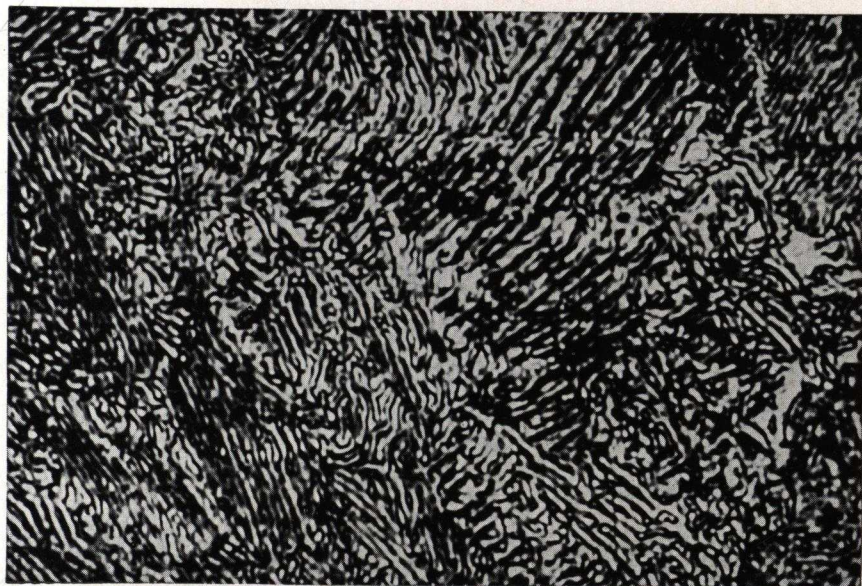


1000 magnifications
(Etched in Nital)
White is ferrite, Dark is pearlite

PEARLITE IN EUTECTOID STEEL

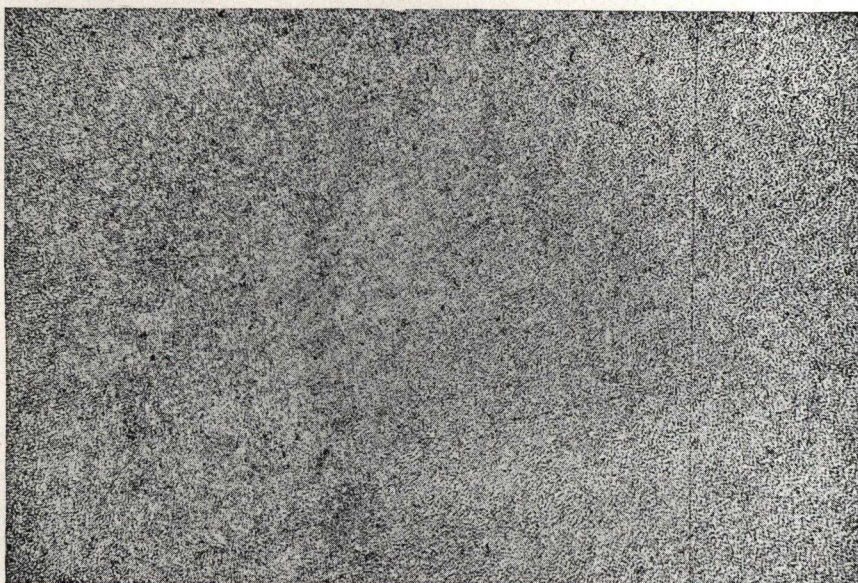


100 magnifications

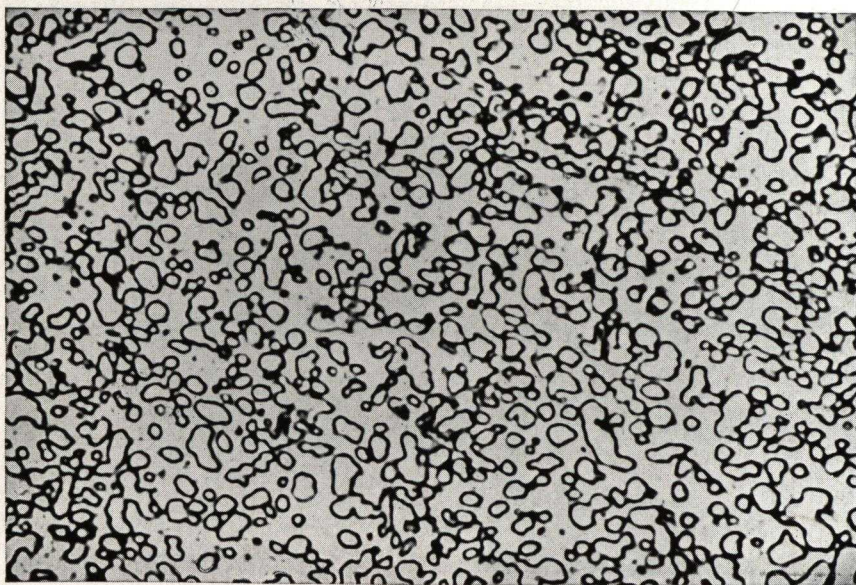


1000 magnifications
(Etched in Nital)
Alternate platelets of ferrite and cementite

SPHEROIDIZED HYPEREUTECTOID STEEL



100 magnifications

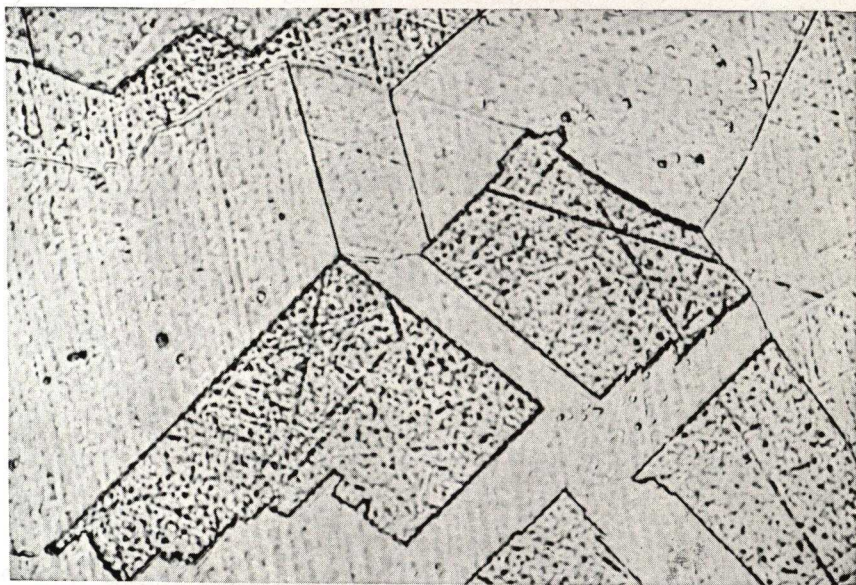


1000 magnifications
(Etched in Nital)
Islands of cementite in ferrite matrix

AUSTENITIC STEEL

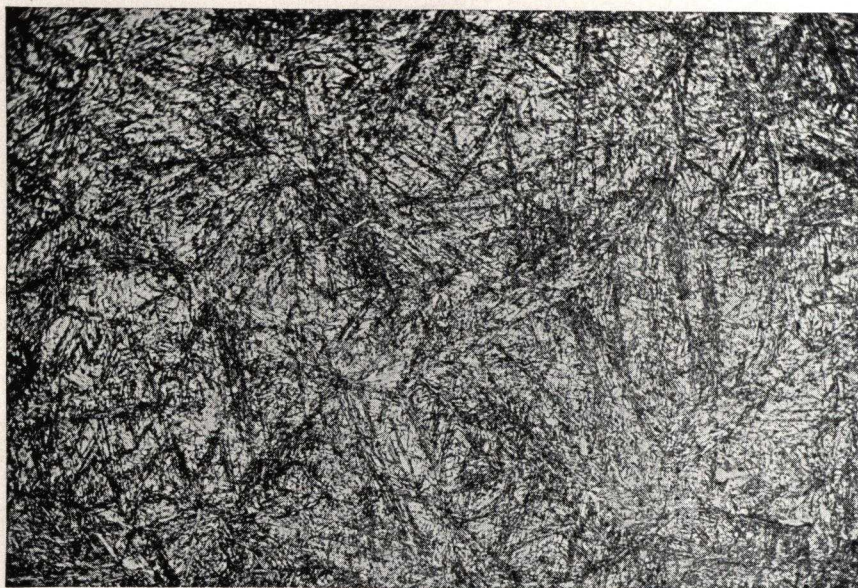


100 magnifications
Typical structure of S. A. E. 30905 steel

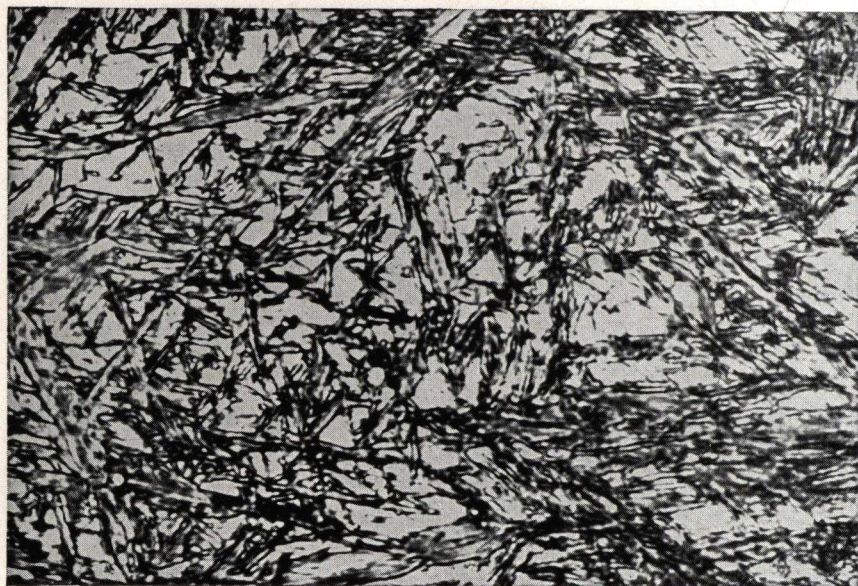


1000 magnifications
Austenite grains in S. A. E. 30905 steel. Etched in Ferric chloride plus HCl
Representative of annealed 18% Chromium, 8% Nickel steel, 2000° F. water-quenched

MARTENSITE IN HYPEREUTECTOID STEEL

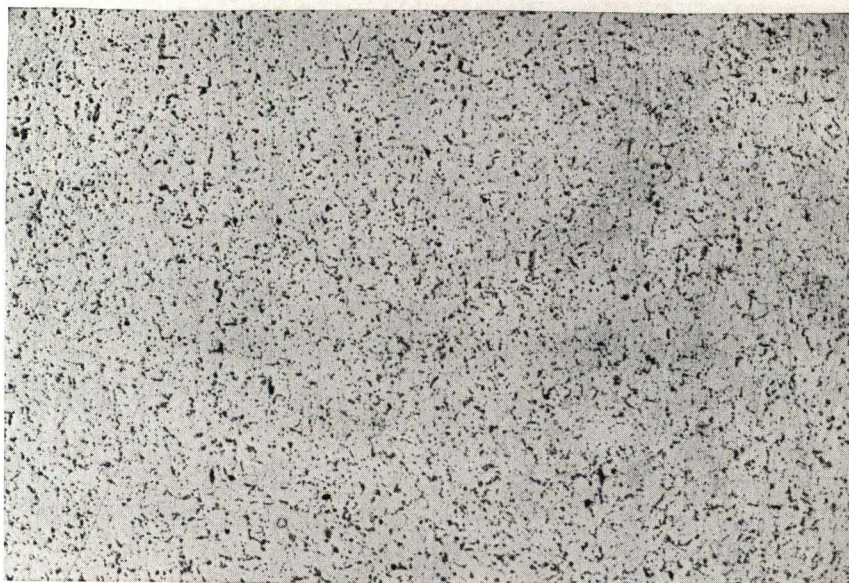


100 magnifications



1000 magnifications
(Etched in Nital)

TROOSTITE



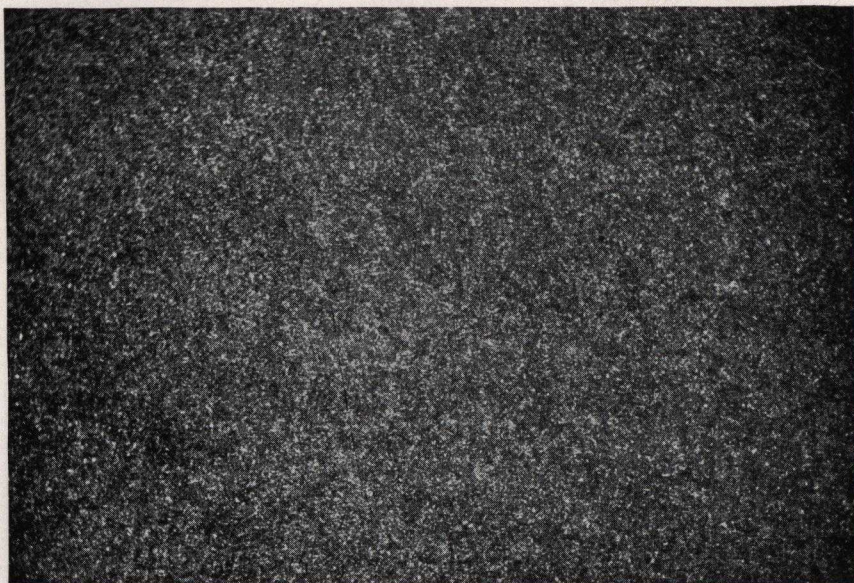
100 magnifications



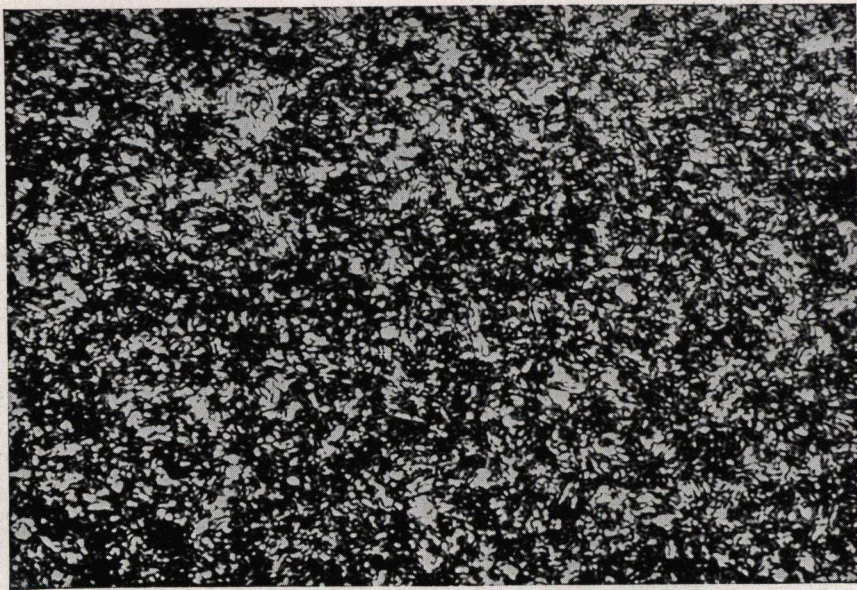
1000 magnifications
(Etched in Nital)

Dark constituent, generally described as troostite, appearing at boundaries of martensitic grains in quenched eutectoid steel

SORBITE IN HYPO-EUTECTOID STEEL



100 magnifications



1000 magnifications
(Etched in Nital)
Alloy steel, quenched and drawn

as shown on page 153-C. Not only is the cementite within the pearlite thus spheroidized but the excess cementite in the boundaries of hypereutectoid steels is also spheroidized.

Most alloy steels, as well as some carbon steels, are heated above G O S K, quenched in either oil or water and then reheated, tempered or drawn, at a temperature below P S K, usually considerably below P S K. Steels thus quenched may show a structure of needle-like character that is indicative of extreme hardness such as is illustrated on page 153-E. This structure has been named martensite and in this instance was obtained by rapidly quenching a piece of high carbon steel. When quenched steels are tempered or drawn at a temperature below the line P S K, the martensitic structure is decomposed. When drawn at low temperatures a dark constituent frequently is observed at the martensitic grain boundaries that has in the past been popularly identified as troostite, see page 153-F. This constituent also may appear in quenched steels if the cooling rate in quenching is not rapid enough to retain all of the constituents in the martensitic state. The results of the work of recent investigations indicate that troostite is a finely divided form of pearlite.

When quenched steels are drawn in a temperature range near the line P S K, finely divided cementite particles appear in the form of spheroids as a result of the decomposition of the martensite and resultant structure is called sorbite, see page 153-G. The properties of steel of this structure are characterized by a good combination of strength and toughness.

The iron-carbon diagram cannot be used to determine correct heat-treating temperatures for alloy steels; these must be determined by actual experience with particular steels or reference to more complex diagrams of complex alloy systems. Nevertheless, in most alloy steels, particularly in those of the structural grade, the alloying elements serve only to intensify certain tendencies found in pure iron-carbon alloys and usually do not tend to produce reactions and products not found in plain carbon steels.

CHEMISTRY

WHETHER steel is made by the open hearth or electric furnace process, the producer has established practices which assure good quality within the range of the chemical limits ordered.

Preliminary tests for control are taken from the molten metal in the furnace at intervals from the time the charge has melted until it is tapped. While the heat is being teemed from the ladle into the molds three samples are obtained, usually after the first and middle ingots are poured and before the last ingot is poured. These are known as ladle tests and their average gives an accurate representation of the chemical composition of the heat.

Standards used by the steel chemists to check against are made available by the United States Government. The Bureau of Standards prepares these standards by securing a sufficient quantity of well mixed chips of the proper size and distributes them to representative laboratories to determine their composition. The results reported, along with those of the Bureau of Standards laboratory, are averaged and this average figure is then set up as the standard. This figure is then always used in conjunction with the standard drillings which are available to the industry which uses them for reference.

The variations reported on these samples by representative and reputable laboratories therefore present a good cross section of the variations which may be anticipated when careful chemists analyze samples of ideal uniformity. These are known as allowable chemists' errors.

Results reported on some of the grades are as follows:

No. of Laboratories
reporting on
samples

		Reported Analyses				
		C.	Mn.	P.	S.	Si.
8	Min. reported	0.403	0.665	0.043	0.024	0.215
	Max. reported	0.430	0.680	0.045	0.027	0.230
11	Min. reported	0.289	0.439	0.025	0.026	0.117
	Max. reported	0.311	0.466	0.029	0.032	0.132

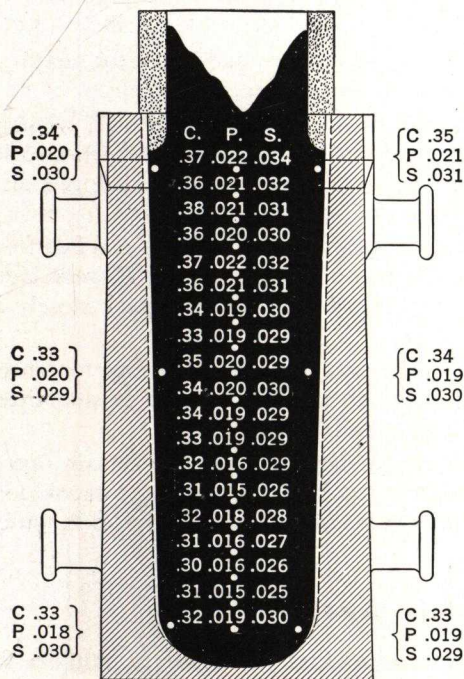
Ni.
3.20
3.28

		Reported Analyses—Continued						
		C.	Mn.	P.	S.	Si.	Cr.	Mo.
12	Min. reported	0.280	0.644	0.014	0.018	0.130	0.90	0.132
	Max. reported	0.310	0.659	0.018	0.024	0.140	0.926	0.160
12	Min. reported	0.480	0.700	0.016	0.009	0.230	Cr. V.	0.225
	Max. reported	0.503	0.718	0.022	0.015	0.243	0.990	0.246
12	Min. reported	0.404	0.614	0.013	0.015	0.210	Ni. Cr.	0.620
	Max. reported	0.420	0.640	0.017	0.020	0.230	1.24	0.653

Check analyses taken from blooms, billets, or bars are subject to another variable in addition to the allowable chemists' errors. The molten steel, after it has been poured into the mold, cannot solidify instantaneously, so the phenomenon of selective freezing manifests itself. The resultant ingot when solidified is, therefore, not entirely uniform chemically, which is the normal state of all steel of commercial sizes and constitutes one of its characteristics.

This variation is found in all ingots. As the size of the ingot increases, the variation is accentuated and cannot be overcome since

the steel maker must use ingots of sufficient size to allow for the necessary hot mechanical work. The accompanying illustration shows a chemical survey of an ingot of the size required to properly process a 3-inch bar.



Drillings taken down center line and along sides

Standard methods of chemical analysis have been developed for the determination of each element.

These comments assume that the important function of sampling has been properly carried out. Accurate laboratory analysis is useless if the sample is not representative of the material.

MANUFACTURERS' STANDARD METHODS OF SAMPLING FOR CHECK ANALYSIS OF ROLLED AND FORGED STEEL PRODUCTS

PRINCIPLES TO BE OBSERVED

1. Different parts of a piece of steel vary in composition. This variation occurs principally between the center and the outside of the piece.
2. When a sufficient number of check analyses have been made on samples properly taken to represent the different portions of a melt, their average compares favorably with the ladle analysis which is the analysis of a small test ingot taken during the pouring of the melt.
3. From this it is evident:
 - (a) That the ladle analysis is more representative of the composition of a melt than any single analysis of the finished material.
 - (b) That drillings for check analysis, to be representative, should be taken at a point intermediate between the outside and the center of the cross section of the material.
 - (c) That a sufficient number of pieces should be analyzed to constitute an average that will afford a fair comparison with the ladle analysis.

PREPARATION OF SAMPLES

4. Each melt in a lot shall be considered separately, and pieces for sampling shall be taken to represent the melt as fairly as possible.
5. Samples must be drillings or chips cut by some machine tool without the application of water, oil or other lubricant, and shall be free from scale, grease, dirt or other foreign substances. If samples are taken by drilling, a drill not less than $\frac{1}{2}$ in. nor more than $\frac{3}{4}$ in. shall be used.
6. Samples must be uniform, well mixed, as fine as possible, and free from dust which causes low-carbon values. Chips too coarse to pass a 20-mesh sieve are not recommended, nor long curly drillings which will not pack closely in the carbon run.
7. In referring samples to the manufacturer or other analysts for check analyses, pieces of the full-size section, when possible, should be submitted rather than cuttings, unless the latter are especially requested.
8. Chemical analysis of material that has been subjected to certain operations does not give results which properly represent its original composition. Therefore samples should be taken from the material in the condition in which it is received from the manufacturer.

LOCATION OF SAMPLES

9. When the material is subject to tension test requirements, samples for check analysis shall be taken from the tension test specimens, or as prescribed in Section 10.

10. When the material is not subject to physical test requirements:

(a) For large sections, including blooms, billets, slabs, rounds, squares, shapes, etc., samples shall be taken at any point midway between the outside and the center of the piece by drilling parallel to the axis. In cases where this method is not practicable, the piece may be drilled on the side, but drillings shall not be taken until they represent the portion midway between the outside and the center. See Fig. 1.

(b) For bored forgings samples shall be taken midway between the inner and outer surfaces of the wall.

(c) For thin material or material of small cross section, such as plates, shapes, bars, etc., if the previous method is not applicable, the samples shall be taken entirely through the material at a point midway between the outside and the center, or by machining off the entire cross section. See Fig. 1.

(d) For sheets the specimen for sampling shall be cut about 2 in. wide, cleaned by pickling or grinding, and then folded once or more by bringing the ends together and closing the bend. The sample for analysis shall be taken in the middle of this length by milling the inside sheared edges or drilling entirely through from the flat surface. Sampling by milling is preferable.

For sheets rolled from slabs or bars longitudinally, the specimen for sampling shall be cut across the full width of the sheet as rolled. For sheets of light gage, more than one specimen may be taken, and stacked together before folding.

For sheets rolled from slabs or bars transversely, the specimen for sampling, about 18 inches long, shall be cut from the side of the sheet and half way between the middle and end as rolled. For sheets of No. 20 gage or lighter, the specimen shall be the full length of the sheet as rolled.

For sheets not of the full size rolled, the sample for analysis shall be taken by milling or drilling the sheet in a sufficient number of places so that the sample is representative of the entire sheet. The sampling may be facilitated by folding the sheet both ways.

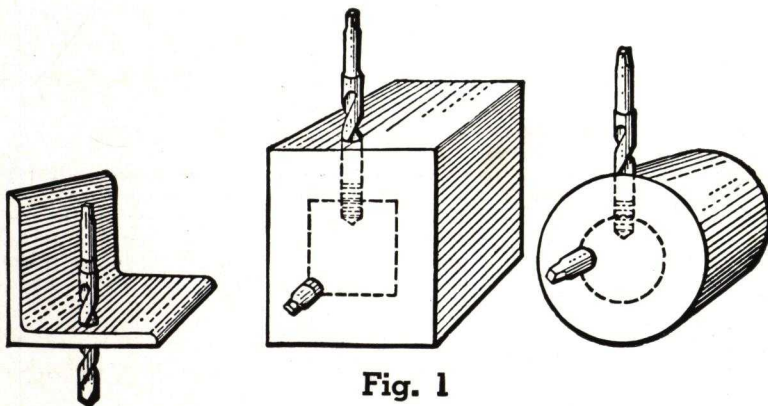


Fig. 1

METHODS OF ANALYSIS

11. Only well-known accurate methods of analysis shall be employed. Carbon shall be determined by the combustion method.

NUMBER OF CHECK ANALYSES

12. (a) Material shall not be subject to rejection for any element or elements unless determinations have been made on the following minimum number of samples from each melt, except as provided in paragraph (b):

- 3 for 5 tons or less;
- 4 for over 5 tons to 10 tons;
- 5 for over 10 tons to 15 tons;
- 6 for over 15 tons.

(b) If the number of pieces of a melt is less than the number of samples specified in paragraph (a), one sample shall be taken from each piece.

MANUFACTURERS' STANDARD LIMITS FOR CHEMICAL COMPOSITION BASED ON LADLE ANALYSIS

(As in effect on date of publication of this book.)

ACID BESSEMER CARBON STEEL*Carbon*

Lowest maximum to be specified 0.08%

When minimum of range ordered is:

	Standard Range
Up to 0.10%, inclusive.....	0.05%
From 0.11 to 0.40%, inclusive.....	0.10%
From 0.41 to 0.60%, inclusive.....	0.15%
From 0.61 to 0.75%, inclusive.....	0.20%

Manganese

Lowest maximum to be specified 0.40%

When minimum of range ordered is:

Up to 0.35%, inclusive.....	0.15%
From 0.36 to 0.60%, inclusive.....	0.20%
From 0.61 to 1.60%, inclusive.....	0.30%

Phosphorus

Lowest maximum to be specified 0.11%

Sulphur

Lowest maximum to be specified 0.06%

When minimum of range ordered is:

Up to 0.075%, inclusive.....	0.07%
From 0.076 to 0.10%, inclusive.....	0.08%
From 0.101 to 0.20%, inclusive.....	0.10%

Silicon

When minimum of range ordered is:

Up to 0.14%, inclusive.....	0.10%
From 0.15 to 0.24%, inclusive.....	0.15%
From 0.25 to 0.40%, inclusive.....	0.20%

Copper

Minimum only to be specified

MANUFACTURERS' STANDARD LIMITS FOR CHEMICAL COMPOSITION BASED ON LADLE ANALYSIS

(As in effect on date of publication of this book.)

BASIC OPEN HEARTH CARBON STEEL

Carbon

Lowest maximum to be specified	0.10%
When minimum of range ordered is:	Standard Range
Up to 0.20%, incl.....	0.05%
From 0.21 to 0.50%, incl.....	0.10%
From 0.51 to 0.95%, incl.....	0.15%
From 0.96 to 1.40%, incl.....	0.20%

Manganese

Lowest maximum to be specified	0.40%
When minimum of range ordered is:	Standard Range
Up to 0.35%, incl.....	0.15%
From 0.36 to 0.60%, incl.....	0.20%
From 0.61 to 1.60%, incl.....	0.30%

Phosphorus

Lowest maximum to be specified	0.04%
When minimum of range ordered is:	Standard Range
Up to 0.04%, incl.....	0.02%
From 0.041 to 0.05%, incl.....	0.025%
From 0.051 to 0.075%, incl.....	0.03%

Sulphur

Lowest maximum to be specified	0.05%
When minimum of range ordered is:	Standard Range
Up to 0.075%, incl.....	0.07%
From 0.076 to 0.10%, incl.....	0.08%

Silicon

When minimum of range ordered is:	Standard Range
Up to 0.14%, incl.....	0.10%
From 0.15 to 0.24%, incl.....	0.15%
From 0.25 to 0.40%, incl.....	0.20%
From 0.41 to 1.80%, incl.....	0.40%

Copper

Minimum only to be specified

ACID OPEN HEARTH CARBON STEEL

Carbon

Lowest maximum to be specified	0.10%
When minimum of range ordered is:	Standard Range
Up to 0.20%, incl.....	0.05%
From 0.21 to 0.50%, incl.....	0.10%
From 0.51 to 0.95%, incl.....	0.15%
From 0.96 to 1.40%, incl.....	0.20%

Manganese

Lowest maximum to be specified	0.45%
When minimum of range ordered is:	Standard Range
Up to 0.35%, incl.....	0.15%
From 0.36 to 0.60%, incl.....	0.20%
From 0.61 to 1.60%, incl.....	0.30%

Phosphorus

Lowest maximum to be specified 0.05%

Sulphur

Lowest maximum to be specified 0.05%

Silicon

When minimum of range ordered is:	Standard Range
Up to 0.14%, incl.....	0.10%
From 0.15 to 0.24%, incl.....	0.15%
From 0.25 to 0.40%, incl.....	0.20%
From 0.41 to 1.80%, incl.....	0.40%

Copper

Minimum only to be specified

MANUFACTURERS' STANDARD PERMISSIBLE VARIATIONS FROM ORDERED CHEMICAL LIMITS BASED ON STANDARD LADLE ANALYSIS RANGES — CARBON STEELS

(As in effect on date of publication of this book.)

PROCEDURE I COMMERCIAL QUALITY REQUIREMENTS

When check analyses are made of the material as furnished, the composition based on the average of all the separate determinations made, may vary from that ordered to the extent permitted in Table I.

Elements	Per cent Under Minimum Limit	Per cent Over Maximum Limit
Carbon—Maximum limits up to 0.80%, inclusive.....	0.02	0.03
Carbon—Maximum limits over 0.80% to 1.15%, inclusive.....	0.03	0.04
Carbon—Maximum limits over 1.15%.....	0.03	0.05
Manganese.....	0.02	0.03
Phosphorus.....	....	0.005
Sulphur.....	....	0.005
Silicon.....	0.02	0.03
Copper.....	0.02	....

Variations both under and over apply only when a range is specified.

PROCEDURE II FORGING QUALITY AND SPECIAL CHECK ANALYSIS REQUIREMENTS

(a) When check analyses are made of the material as furnished, the composition based on the average of all the separate determinations made, shall be within the limits ordered.

(b) The composition of individual samples may vary from that ordered to the extent permitted in Table II, except that when ranges are specified, the carbon, the manganese, or the silicon in any one melt may not vary both above and below the range ordered.

Elements	Per cent Under Minimum Limit	Per cent Over Maximum Limit
Carbon—Maximum limits up to 0.25%, inclusive.....	0.02	0.03
Carbon—Maximum limits over 0.25% to 0.60%, inclusive.....	0.03	0.04
Carbon—Maximum limits over 0.60% to 1.15%, inclusive.....	0.03	0.05
Carbon—Maximum limits over 1.15%.....	0.03	0.06
Manganese.....	0.05	0.05
Phosphorus.....	....	0.01
Sulphur.....	....	0.01
Silicon.....	0.02	0.05
Copper.....	0.02	....

PROCEDURE III

EXTRA RESTRICTIVE CHECK ANALYSIS REQUIREMENTS

(a) When check analyses are made of the material as furnished, the composition based on the average of all the separate determinations made, shall be within the limits ordered.

(b) The composition of individual samples may vary from that ordered to the extent permitted in Table III, except that when ranges are specified, the carbon, the manganese, or the silicon in any one melt may not vary both above and below the range ordered.

TABLE III
Elements

	Per cent Under Minimum Limit	Per cent Over Maximum Limit
Carbon.....	0.02	0.02
Manganese.....	0.03	0.03
Phosphorus.....	....	0.005
Sulphur.....	....	0.005
Silicon.....	0.02	0.02
Copper.....	0.02	....

EXCEPTIONS

(a) Standard permissible variations for check analyses are not applicable to rimmed steel.

(b) Rephosphorized and resulphurized steel shall not be subject to check analyses for phosphorus or sulphur.

(c) When both minimum and maximum limits are ordered, giving a range greater than the Standard ladle analysis range; unless otherwise specified by the purchaser, the permissible variations for check analyses shall be applied to the Standard ladle range the mean of which will coincide with the mean of the ordered range. In no case shall an ordered range which includes check analyses limits be less than the sum of the ladle range and the permissible under and over check variations.

ALLOY STEEL — HOT-ROLLED**RANGES IN CHEMICAL COMPOSITION BASED ON
LADLE ANALYSIS***(As in effect on date of publication of this book.)***BASIC OPEN HEARTH ALLOY
STEELS****Carbon**

When maximum of range ordered is	Standard Range
Up to 0.25%, incl.....	0.05%
From 0.26 to 0.40%, incl.....	0.06%
From 0.41 to 0.55%, incl.....	0.07%
From 0.56 to 0.85%, incl.....	0.10%
From 0.86 to 1.10%, incl.....	0.15%
From 1.11 to 1.50%, incl.....	0.20%

Manganese

Lowest maximum to be specified 0.40%

When maximum of range ordered is	Standard Range
Up to 0.40%, incl.....	0.15%
From 0.41 to 0.60%, incl.....	0.20%
From 0.61 to 2.00%, incl.....	0.30%

Phosphorus

Lowest maximum to be specified 0.04%

Sulphur

Lowest maximum to be specified 0.04%

Silicon

When maximum of range ordered is	Standard Range
From 0.31 to 1.00%, incl.....	0.20%
From 1.01 to 2.50%, incl.....	0.40%

Nickel

When maximum of range ordered is	Standard Range
Up to 1.00%, incl.....	0.20%
From 1.01 to 2.00%, incl.....	0.35%
From 2.01 to 6.00%, incl.....	0.50%

Chromium

When maximum of range ordered is	Standard Range
Up to 0.45%, incl.....	0.20%
From 0.46 to 1.25%, incl.....	0.30%
From 1.26 to 1.75%, incl.....	0.50%

**ELECTRIC FURNACE ALLOY
STEELS****Carbon**

When maximum of range ordered is	Standard Range
Up to 0.55%, incl.....	0.05%
From 0.56 to 0.85%, incl.....	0.10%
From 0.86 to 1.50%, incl.....	0.15%

Manganese

Lowest maximum to be specified 0.40%

When maximum of range ordered is	Standard Range
Up to 0.60%, incl.....	0.15%
From 0.61 to 1.20%, incl.....	0.20%
From 1.21 to 2.00%, incl.....	0.30%

Phosphorus

Lowest maximum to be specified 0.025%

Sulphur

Lowest maximum to be specified 0.025%

Silicon

When maximum of range ordered is	Standard Range
From 0.31 to 1.00%, incl.....	0.20%
From 1.01 to 2.50%, incl.....	0.35%

Nickel

When maximum of range ordered is	Standard Range
Up to 1.00%, incl.....	0.20%
From 1.01 to 2.00%, incl.....	0.35%
From 2.01 to 6.00%, incl.....	0.50%

Chromium

When maximum of range ordered is	Standard Range
Up to 0.40%, incl.....	0.10%
From 0.41 to 0.80%, incl.....	0.20%
From 0.81 to 2.00%, incl.....	0.30%
From 2.01 to 3.99%, incl.....	0.40%
From 4.00 to 6.00%, incl.....	1.00%

RANGES IN CHEMICAL COMPOSITION—Continued

BASIC OPEN HEARTH ALLOY
STEELS*Vanadium*

When maximum of range ordered is	Standard Range
Up to 0.25%, incl.....	0.05%
From 0.26 to 0.50%, incl.....	0.10%

Molybdenum

When maximum of range ordered is	Standard Range
Up to 0.20%, incl.....	0.05%
From 0.21 to 0.50%, incl.....	0.10%
From 0.51 to 1.00%, incl.....	0.15%

Tungsten

When maximum of range ordered is	Standard Range
Up to 0.50%, incl.....	0.20%
From 0.51 to 1.00%, incl.....	0.30%
From 1.01 to 2.00%, incl.....	0.50%
From 2.01 to 4.00%, incl.....	0.60%

Incidental Alloys

Chromium (max.)	0.20%
Nickel (max.)	0.25%
Copper (max.)	0.25%

ELECTRIC FURNACE ALLOY
STEELS*Vanadium*

When maximum of range ordered is	Standard Range
Up to 0.25%, incl.....	0.05%
From 0.26 to 0.50%, incl.....	0.10%

Molybdenum

When maximum of range ordered is	Standard Range
Up to 0.20%, incl.....	0.05%
From 0.21 to 0.50%, incl.....	0.10%
From 0.51 to 1.00%, incl.....	0.15%

Tungsten

When maximum of range ordered is	Standard Range
Up to 0.50%, incl.....	0.20%
From 0.51 to 1.00%, incl.....	0.30%
From 1.01 to 2.00%, incl.....	0.50%
From 2.01 to 4.00%, incl.....	0.60%

Incidental Alloys

Chromium (max.)	0.20%
Nickel (max.)	0.25%
Copper (max.)	0.15%

When check analyses are made of the material as furnished, the composition based on average of all the separate determinations made shall be within the limits ordered.

The composition of individual samples may vary from that ordered to the extent permitted in the attached table, except that when ranges are specified the elements in any one melt may not vary both above and below the range ordered.

	Under	Over
Carbon.....	0.02 %	0.02 %
Manganese—		
Up to 0.90%, incl.....	0.03 %	0.03 %
From 0.91 to 2.00%, incl.....	0.06 %	0.06 %
Phosphorus.....	0.005%	0.005%
Sulphur.....	0.005%	0.005%
Silicon—		
Up to 0.40%, incl.....	0.02 %	0.02 %
From 0.41 to 2.20%, incl.....	0.05 %	0.05 %
Copper.....	0.02 %	.....
Nickel—		
Up to 1.00%, incl.....	0.05 %	0.05 %
1.01 to 2.00%, incl.....	0.08 %	0.08 %
2.01 to 6.00%, incl.....	0.10 %	0.10 %
Chromium—		
Up to 0.45%, incl.....	0.04 %	0.04 %
From 0.46 to 1.75%, incl.....	0.05 %	0.05 %
Vanadium.....	0.03 %	0.03 %
Tungsten—		
Up to 1.00%, incl.....	0.05 %	0.05 %
From 1.01 to 4.00%, incl.....	0.10 %	0.10 %
Molybdenum.....	0.03 %	0.03 %

COMPOSITION HARDNESS

BY ASSIGNING values for the various elements in steel, other than iron, it is possible approximately to compare alloy steels of the same inherent qualities in their degree of response and strength developed when properly heat treated under identical conditions, i.e., size of part, temperatures, etc.

Values which may be used for the various elements are:

Carbon 0.01% = 30	Silicon 0.01% = 5	Vanadium . . . 0.01% = 20
Manganese . . . 0.01% = 8	Nickel 0.01% = 4	Molybdenum . 0.01% = 16
Phosphorus . . . 0.001% = 4	Chromium . . . 0.01% = 5	Tungsten . . . 0.01% = 4
Sulphur 0.001% = 1		Copper 0.01% = 4

These factor figures have been found useful in comparing heats of steel containing the same elements. They, however, are not infallible when comparing one type of steel with another, since the value of any of these alloying elements varies, depending on whether it is the sole alloying element or whether added in combination with other alloying elements.

As an example of the application of this quick method, compare the hardness factor of two grades. It was suggested on page 63 that S. A. E. 3240 steel be substituted for S. A. E. 3140 when the stresses in service were so high that a stronger steel must be used. Using the mean analysis of S. A. E. 3140 and 3240 as the basis for comparison we find S. A. E. 3140 has a composition hardness of 2,835, while S. A. E. 3240 has a composition hardness of 3,035.

S.A.E. 3140		S.A.E. 3240	
Carbon	$40 \times 30 = 1200$	Carbon	$40 \times 30 = 1200$
Manganese	$75 \times 8 = 600$	Manganese	$45 \times 8 = 360$
Phosphorus	$25 \times 4 = 100$	Phosphorus	$25 \times 4 = 100$
Sulphur	$35 \times 1 = 35$	Sulphur	$35 \times 1 = 35$
Silicon	$20 \times 5 = 100$	Silicon	$20 \times 5 = 100$
Nickel	$125 \times 4 = 500$	Nickel	$175 \times 4 = 700$
Chromium	$60 \times 5 = 300$	Chromium	$108 \times 5 = 540$
2,835		3,035	

Arithmetical methods for obtaining the approximate tensile strength of rolled carbon steel are:

$$T.S. = C \times 650 + M \times 90 + M \times C \times 4 + P \times 1000 + 38800$$

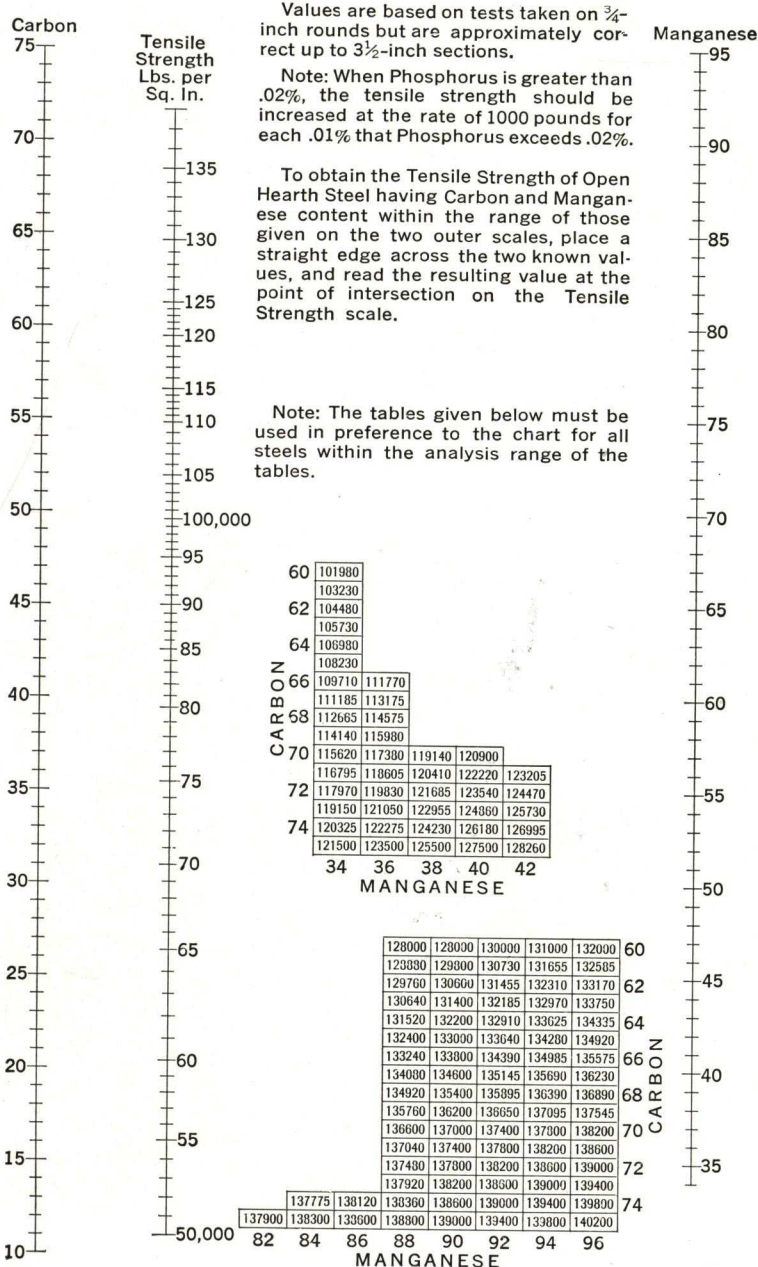
$$T.S. = C \times 950 + M \times 85 + P \times 1050 + 37430$$

$$T.S. = C \times (650 + 4M) + P \times 1000 + M \times 90 + 38800$$

Note: Move the decimal points two places to the right when substituting numbers which indicate amount of elements, C, M, P.

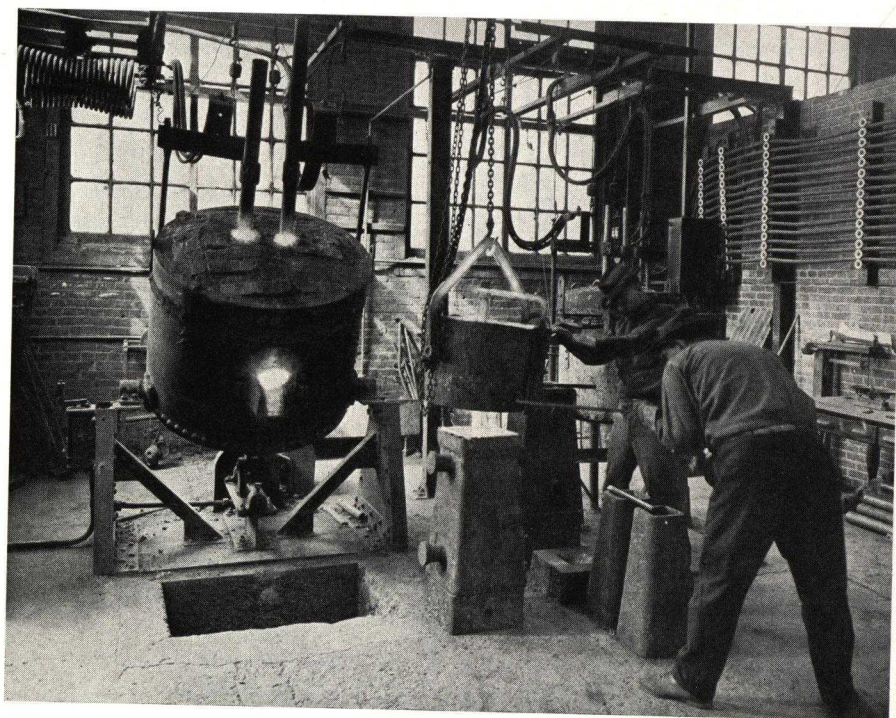
The chart on page 165 has been found valuable for finding the tensile strength of rolled carbon steel.

CHART FOR ESTIMATING TENSILE STRENGTH OF ROLLED CARBON STEEL





Experimental heat-treating department (Metallurgical division)



Experimental steel making department (Metallurgical division)

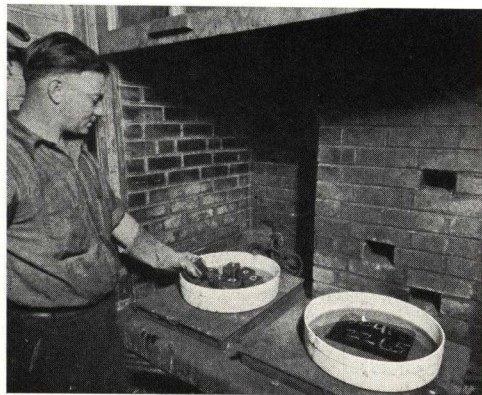
HOT ACID ETCHING

THIS test is most widely used as a measure in manufacturing control rather than as an acceptance test and is therefore usually applied to blooms and billets rather than to small size bars. While there have been published standard methods for conducting the hot acid etch test, there are no recognized standards of acceptance or rejection for steel so tested. The ultimate use for which the product is intended must be the guide.

Since the interpretation of the results cannot be governed by any published standards, this test therefore is a highly specialized operation. If the hot acid etch test is specified, it is recommended that a thorough understanding regarding acceptability limits be made by the parties involved.

To carry out this test, a cross section disc ranging from $\frac{1}{2}$ to 1 inch thickness is used. If the machine or saw cut is smooth, no additional preparation is necessary; if not, a smooth milling cut should be taken across the surface, or as an alternate, the face should be ground.

The specimen should then be immersed in a hot acid solution (usually HCl , approximately 1.08 specific gravity). The time required in the acid depends on the analysis of the steel being



Hot acid etching includes samples from every heat of alloy and special quality steels

tested, the mass of the specimen, the conditions to be studied, and other mechanical or thermal conditions. Carbon steel generally requires a shorter time than alloy steels. The time required ranges from 30 to 45 minutes to properly etch the sample. It is recommended in carrying out this test that the sample be removed from the acid etch bath and inspected occasionally to see if it has been sufficiently etched and, further, to prevent over-etching which gives erroneous results. The variations that may be expected due to improper etching time are shown by illustrations on pages 169 to 171.

Page 169 shows sample A, a billet of uniform macrostructure, and sample B, a billet of non-uniform macrostructure, both etched ten minutes.

Page 170 shows the same two samples etched the proper time for the grade of steel.

Page 171 shows the same two samples etched a longer period.

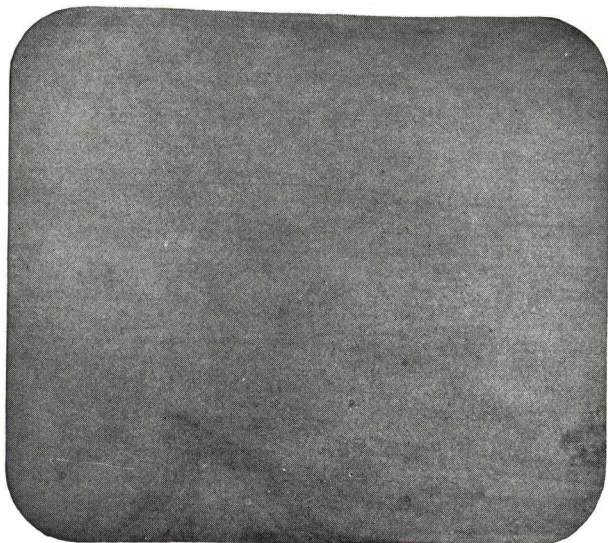
It is obvious that when properly etched, the uniform sample A is superior to B, but when over-etched the non-uniform sample B appears to be nearly as uniform as sample A.

This test, when properly carried out, gives valuable information regarding the internal condition of the steel. Improper procedure or wrong interpretation may mean on one hand, approval of steel not up to the standard desired, or, on the other hand, rejection of steel which is entirely suitable.

Some of the conditions of the steel developed by this etch test are shown by illustrations on pages 172 to 174. These illustrations are not presented to define in any sense suitable or non-suitable material but are used only to amplify the comments on hot acid etching.

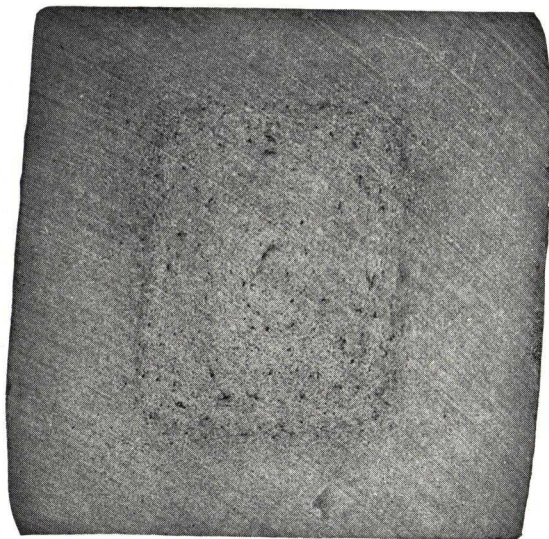
HOT ACID ETCH TEST EXAMPLES

A



Etched 10 minutes

B

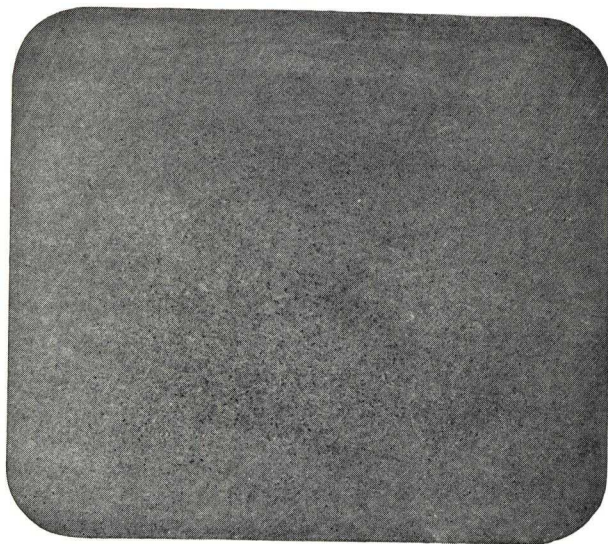


Etched 10 minutes

Photographs of hot acid etched 4-inch billets

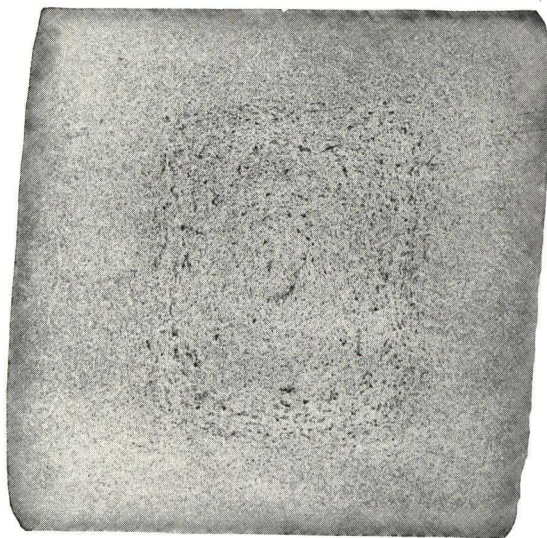
HOT ACID ETCH TEST EXAMPLES

A



Properly etched

B

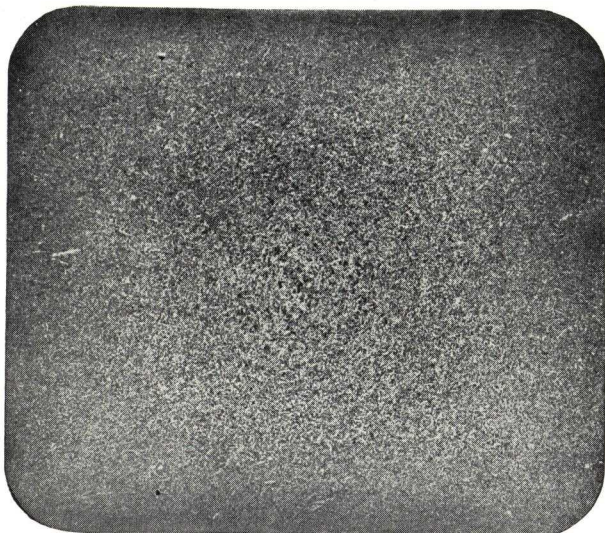


Properly etched

Photographs of hot acid etched 4-inch billets

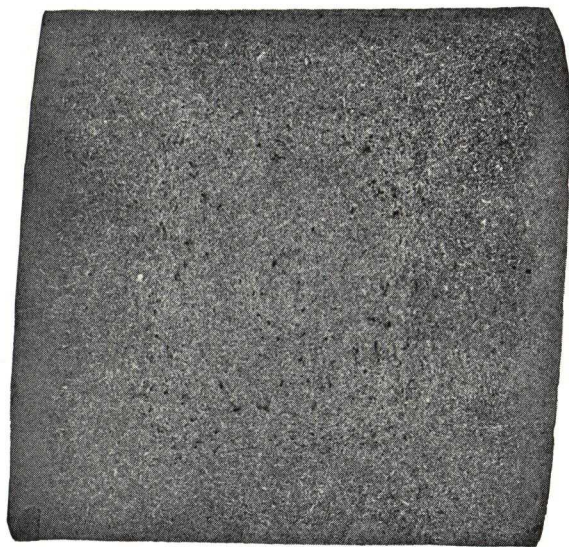
HOT ACID ETCH TEST EXAMPLES

A



Over etched

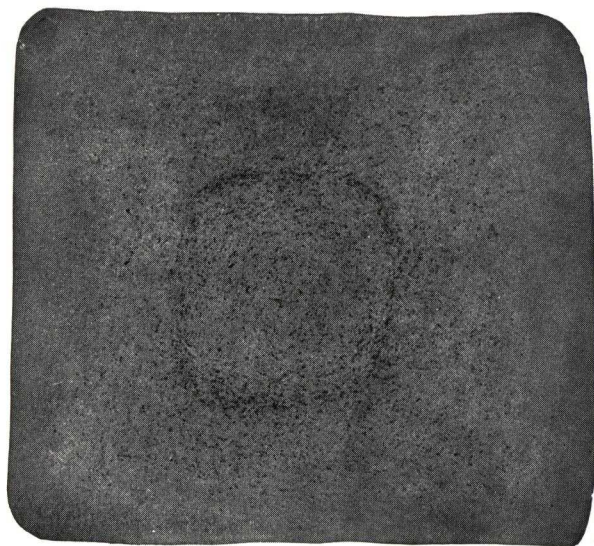
B



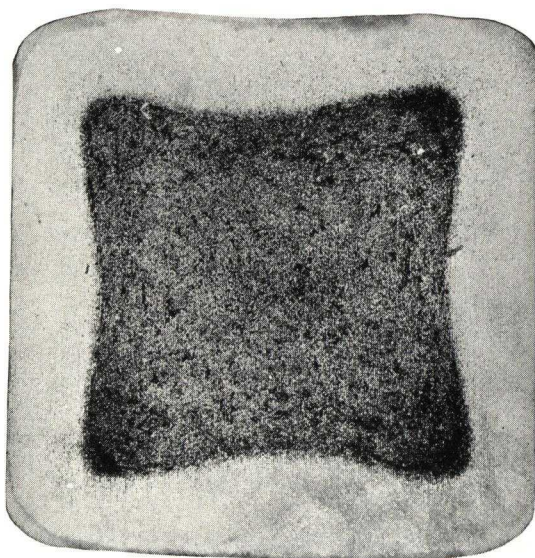
Over etched

Photographs of hot acid etched 4-inch billets

HOT ACID ETCH TEST EXAMPLES



Mold pattern

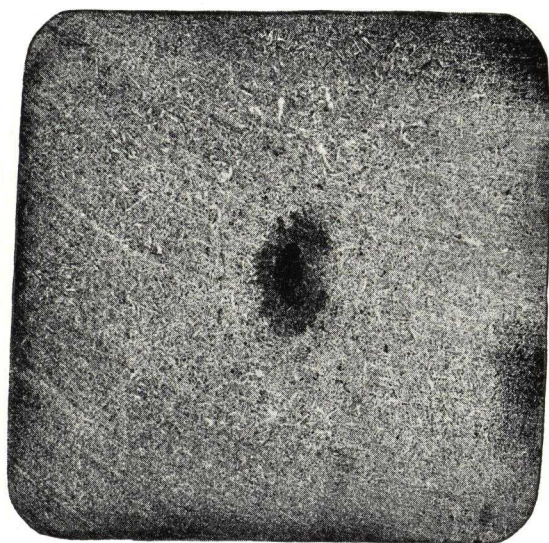


Rimmed steel

(Not used in alloy steel practice)

Photographs of hot acid etched 4-inch billets

HOT ACID ETCH TEST EXAMPLES



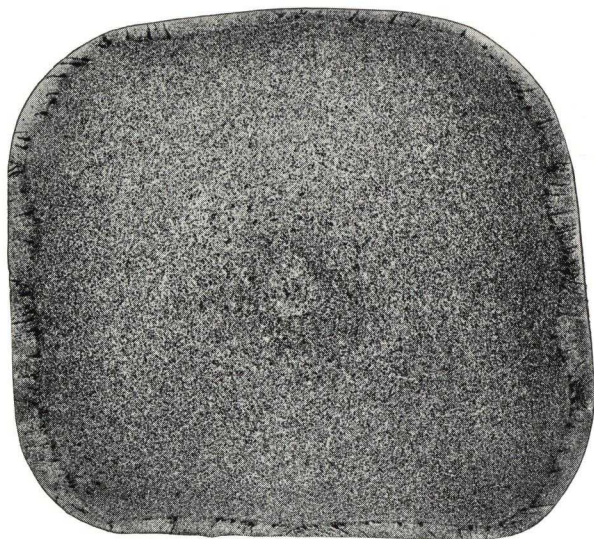
Segregation and pipe



Deoxidized steel

Photographs of hot acid etched 4-inch billets

HOT ACID ETCH TEST EXAMPLES



Porosity due to mold action



Internal cracks

Photographs of hot acid etched 4-inch billets

TENSION TEST TERMS

THE tension test of steels consists of applying a pulling force to a specimen of material and recording the reactions that occur. In steel, these reactions occur in two distinct phases; the elastic phase wherein the material is not permanently deformed by the pulling force, and the plastic or yield phase wherein the material becomes either permanently deformed or ruptured.

For the service use of material, the greatest concern is that the maximum force or load encountered shall always be within the elastic range. The terms used for expressing the limiting value of the elastic range have in the past been very loosely applied, leading to confusion as to the degree of precision contemplated by the writers of specifications. Therefore, it appears pertinent to define these terms in the order of their occurrence in testing, which are: proportional limit, elastic limit, proof stress, yield strength and yield point.

PROPORTIONAL LIMIT

The proportional limit of a material is the load per unit area beyond which the increases in strain cease to be directly proportional to the increases in stress. In the tension test, the specimen is placed in the testing machine with an extensometer attached. If accurately measured loads are progressively applied and the resultant strain movements recorded, and if these data are plotted as the ratio of load to strain, it will be found that up to a certain point this ratio will be practically a straight line. The load value at this point represents the proportional limit of the material, or the limit of proportionality of stress to strain. Within this limit, the ratio of unit stress to unit strain is called the *Modulus of Elasticity*. The graph from which these values are obtained, may be plotted from observed and recorded data or it may be autographically drawn by an automatic recorder.

The proportional limit, as described above, is used mainly in research investigations and has very few commercial applications. The test procedure is tedious and requires very delicate instruments and highly trained operators.

ELASTIC LIMIT

The elastic limit of a material is the greatest load per unit area which will not produce a measurable permanent deformation after complete release of load.

This value lies somewhere above the proportional limit and below the yield values. According to a strict interpretation of the definition, it can only be obtained by repeated loading and unloading of increasing loads by measured increments of stress and noting the permanent elongation, if any, after each release of load. The maximum load, thus found, not producing a measurable elongation after complete release would thus be the elastic limit.

This method of test, however, as indicated both by published and private data, is impractical, tending to produce variable elastic limit values due to slippage, cold working, etc., in carrying out the test. It is therefore recommended that when elastic limit values are desired, that they be obtained by plotting a stress-strain curve in the same manner as described under proportional limit, either from observed or autographically recorded data, and the elastic limit value be taken as the load per unit area, corresponding to the point at which the stress-strain curve departs from the modulus line in excess of a previously agreed limiting amount.

PROOF STRESS

The proof stress of a material is that load per unit area which a material is capable of withstanding without resulting in a permanent deformation of more than a specified amount per unit of gage length after complete release of load.

The definition of this value also states that it shall be determined by repeated applications and releases of measured increments of load. The suitability of proof stress determinations of elastic properties in connection with practical testing is dependent entirely on the amount of permissible permanent elongation specified. In cases where the allowable permanent elongation is less than 0.01 per cent of gage length, the same remarks apply as were given under elastic limit.

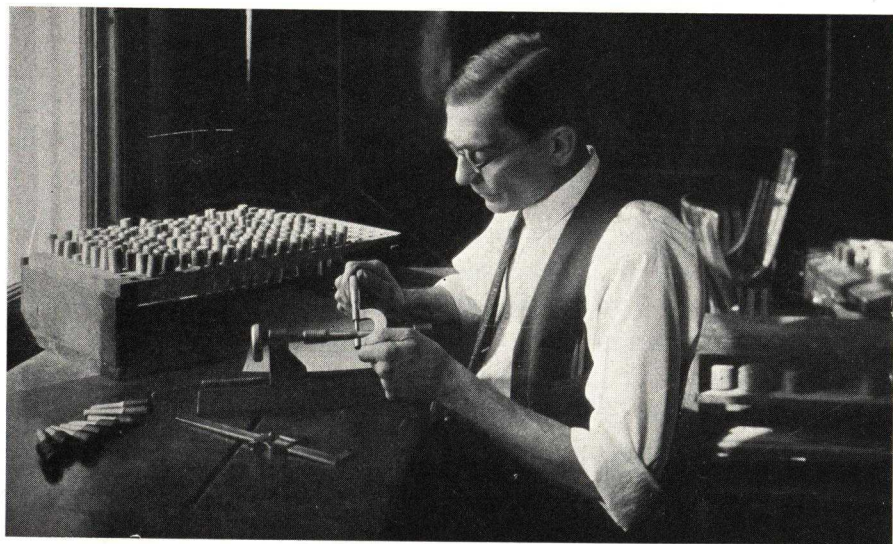
YIELD STRENGTH

The yield strength is the load per unit area at which a material exhibits a specified permanent deformation or a specified elongation under load.

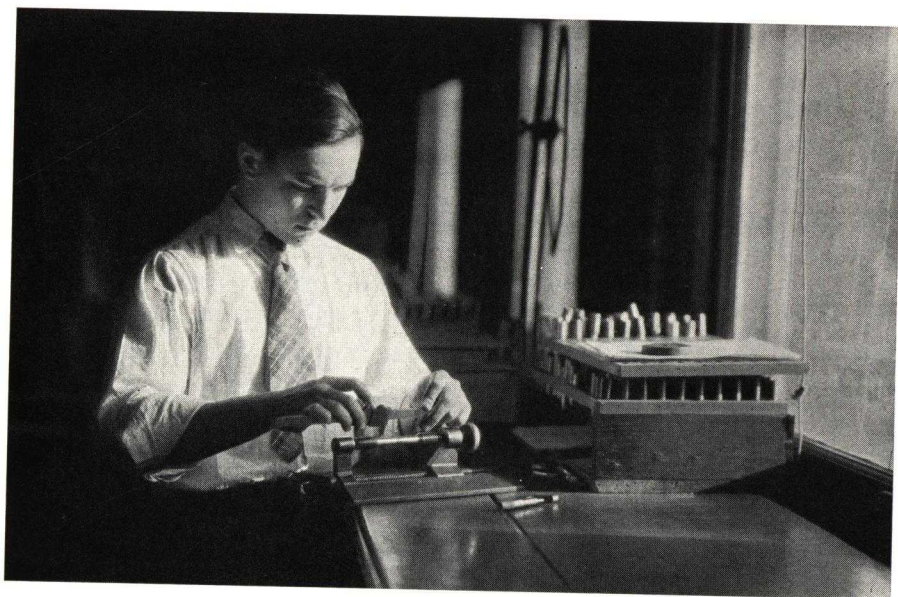
This value may be determined in the same manner as has been suggested for determining elastic limit except that the specified amount of departure of the stress-strain curve from the modulus line is usually 0.1 per cent to 0.2 per cent of the gage length. It may also be obtained by any one of the following methods:

Proportional Method—The yield strength shall be calculated at the reading last preceding the first increment of load which produces an increment of strain which clearly exceeds twice the increment of strain taken from the modulus line.

Extension Under Load Method—The yield strength shall be the unit applied load at which the material exhibits the specified extension under load. It shall be determined by applying the extensometer to the test specimen when there is no load on the specimen, and then increasing the load, taking readings at approximately 75 and 90 per cent of the specified elongation and at the specified elongation. If the stress at the specified elongation



Tension tests. Measuring reduction



Tension tests. Measuring elongation

equals or exceeds the specified yield strength the material is acceptable as to yield strength.

The Divider Method—This is the same as that described below for determining the yield point by use of dividers or a strainometer.

YIELD POINT

The yield point is the load per unit area at which a marked increase in deformation of the specimen occurs without increase of load, or in other words, the yield point is the stress at which there occurs a marked increase in strain without an increase in stress.

Since the speed of testing influences the results, this feature must be taken care of by keeping the crosshead speed of the testing machine (or the rate of application of the load) within well defined limits. A. S. T. M. (E8-33) recommends that in determining yield strength, the crosshead speed for the 2-inch gage length shall not exceed 0.125 inch per minute.

The yield point is usually determined by one of the following two methods:

Drop of Beam—In this method the load is applied at a steady rate with the beam kept in balance by running out the poise weight at a steady rate. When the yield point is reached the increase in the rate of strain causes an interruption in the rate of load application (for some metals there is an actual falling off of load) and the beam of the testing machine drops for a brief but appreciable period of time. The load at the drop of beam (or halt of gage in hydraulic-type machines) is recorded and that stress taken as the yield point of the material being tested. In case the testing machine is fitted with a self-indicating load measuring device, there is a sudden halt of the load-indicating pointer, corresponding to the drop of beam.

Divider Method—A pair of dividers are set exactly to the distance between centers of the gage marks. With a small initial load on the specimen, one arm of the dividers will be centered in one gage mark and the other arm is held against the other gage mark. When any movement of the gage mark with respect to the free arm of the divider can be detected by the eye, the applied load is noted. The applied load divided by the area of the original cross section of the test specimen is taken as the yield point. A strainometer may be used in place of the dividers. This method should be used only where the distance between gage marks is not greater than 2 inches. Longer gage lengths are liable to lead to erroneous results, especially in materials of relatively high yield point.

TENSILE STRENGTH

The tensile strength is the maximum load per unit area which a material is capable of withstanding. It is computed from the maximum load carried during a tension test and the original cross-sectional area of the specimen.

PERCENTAGE ELONGATION

The percentage elongation is the difference in the gage length before being subjected to any stress and after rupture, expressed as a percentage of the original gage length.

PERCENTAGE REDUCTION OF AREA

The percentage reduction of area is the difference between the original cross-sectional area and the least cross-sectional area after rupture, expressed as a percentage of the original cross-sectional area.

In considering the determination of those values for which a method has been suggested that involves the plotting of a stress-strain curve, there are several factors that should be borne in mind.

The machine used must be sensitive to small load changes and be very accurate. The instrument used for measuring elongation or strain must be of sufficient sensitivity so that reactions to small loads can be recognized readily and accurately.

Whenever any method is applied involving the use of an extensometer it is well to apply a small initial load, usually 5000 pounds per square inch, before taking the readings. This will take up any looseness or play in the equipment and set-up, and give more consistent results and a clearer modulus line.

With some specimens, particularly from as-rolled or cold-worked material, it will be found that the stress-strain curve exhibits a slight curvature over practically the entire elastic range, or a departure from the straight line relationship within the elastic range. This is evidence of unrelieved strains which should be removed by a stress-relieving treatment on the part from which the tests are taken if determinations of accurate elastic values are attempted. Generally speaking the determination of elastic properties with the use of the extensometer is more applicable to heat-treated material than to as-rolled, cold-worked, or untreated products.

Regardless of the method used in tension testing or the degree of sensitivity of the testing equipment, the personal element cannot be overlooked. Accurate results require well-trained and experienced operators.

UNITS USED IN THE MEASUREMENT OF PERMANENT MAGNETS

SMALL magnets are usually magnetized by placing them directly on the pole pieces of a large electromagnet. Where heavier sections are encountered, this procedure is not always satisfactory since the permeability of the pole pieces limits the flux available for doing the work. In such cases it is desirable to place the magnet inside of a solenoid, which practice usually requires a special coil wound to fit the shape of the magnet.

Magnetomotive Force—The magnetizing influence of a solenoid is governed by the number of turns of wire it contains and the current flowing through it. Thus it is possible to secure the same effective magnetizing influence by using a small number of turns in connection with a heavy current as when using a large number of turns and a small current. This magnetizing influence is known as magnetomotive force and is measured in the c.g.s. system by a unit called the gilbert. The gilbert can best be defined by considering the following relationship:

$$F = 0.4 \pi NI$$

Where F—Magnetomotive Force (gilberts)
N—Number of turns on solenoid
I—Current in amperes

Magnetic Flux—When a specimen of magnet steel is properly hardened and magnetized, it is said to produce a magnetic flux in the space between its poles. By cutting this field or flux with some suitable coil of wire, it is possible to generate an electric current in the coil. This principle is used to define the unit of flux since it would be virtually impossible to measure it in any direct way. The unit of flux is called the maxwell and its magnitude is such that when the flux cut by a single turn of wire varies at the rate of 100,000,000 maxwells per second, a potential of one volt is picked up by the wire.

Magnetic Induction—The unit of magnetic induction is known as the gauss and represents the density of magnetic flux across any section normal to the direction of flux. Across any section wherein the flux is uniformly distributed the magnetic induction

in gaussses can be calculated by the following relation:

$$B = \frac{M}{S} \quad \begin{array}{l} \text{Where } B = \text{Induction in gaussses} \\ M = \text{Flux in maxwells} \\ S = \text{Area of section in square centimeters} \end{array}$$

Magnetic Reluctance—In any magnetic circuit the useful magnetic flux is limited by the reluctance or resistance of that circuit. The unit of magnetic reluctance is the oersted and is defined by Ohm's law of magnetic circuits.

$$\text{oersteds} = \frac{\text{gilberts}}{\text{maxwells}}$$

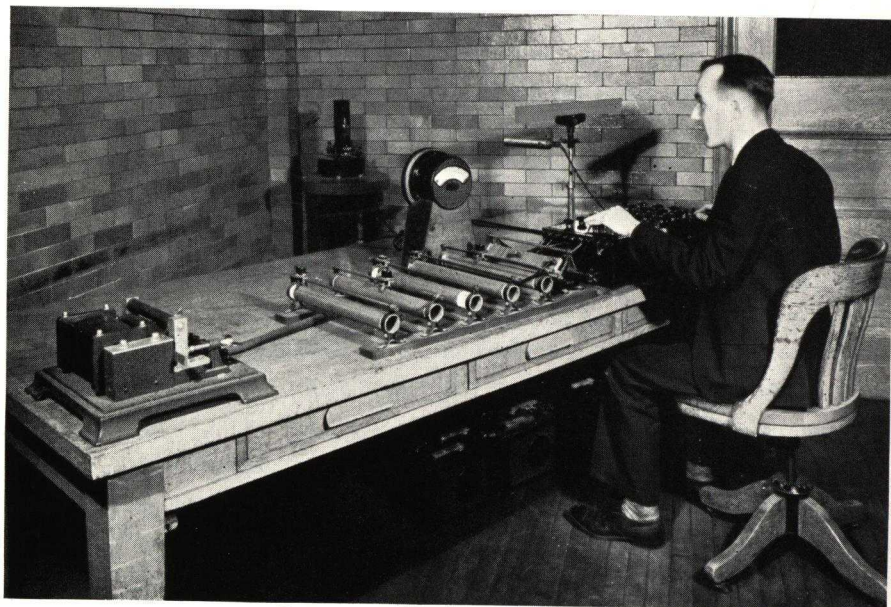
Magnetic Permeability—The ratio of magnetic induction to its corresponding magnetizing force is known as magnetic permeability.

$$\text{Permeability} = \frac{\text{gaussses}}{\text{oersteds}}$$

Residual Induction (B_r)—The magnetic induction remaining in a specimen of magnet steel after the magnetizing force has been reduced to zero. The unit used to measure residual induction is the gauss.

Coercive Force (H_c)—The reversed magnetizing force that is just sufficient to reduce the residual induction to zero. The unit of coercive force is the oersted.

NOTE: For further information see A. S. T. M. Proceedings Vol. 31, Part I, 1931; also 1933 A. S. T. M. Tentative Standards.



Equipment for testing magnet steels

PART 4

WORKING OF STEEL

QUENCHING MEDIA

PYROMETERS

LIQUID HEATING BATHS

COLOR CHARTS

HEATING STEEL

REFRACTORIES

QUENCHING MEDIA

QUENCHING media are used to remove heat from the surface of steel to develop certain desired properties in the metal. The properties generally sought are increased hardness and strength, and crystalline refinement. There are several factors involved in the selection of quenching media.

Certain grades of steel, on account of the high critical cooling rate necessary for hardening, can be hardened only a moderate depth below the surface. In this class, to which the widely used carbon steels belong, a quenching medium that has a fast cooling rate is required. Additions of alloying elements to steels lower the critical cooling rate and thereby permit the use of quenching media that have a slower cooling rate.

Hardness of steel developed by quenching, distortion, and residual stresses are functions of the cooling rate of quenching media during hardening and therefore must be considered when selecting a medium for quenching.

Contrary to the old belief that heat from metal is dissipated by convection, the actual cooling of the metal surface in the early stages of quenching is accomplished by the formation and motion of vapor of the liquid. It is not until the surface of the metal reaches about 500°-600° F. that convection cooling by the quenching liquid begins. It has been found that the quenching medium should be most effective when the steel reaches about 1000°F. Effectiveness of the quenching operation is always improved through rapid circulation of the quenching medium or rapid movement of the cooling part in the medium. This action wipes away the gas bubbles as they are formed in the early stage of the operation and as the piece cools brings the cooler quenching liquid in contact with the piece.

The most common types of quenching media include (1) water and aqueous solution of salts, acids and alkalies, and (2) oils: mineral, vegetable and animal. Comparative quenching rates, with still water at 68°F. as the base unit of comparison, are given by A. S. M. as follows:

Quenching Medium	Relative Quenching Rate
Still water at 68° F.....	1.00
Still 5% Sodium Chloride at 68° F.....	1.12
Still 5% Sodium Hydroxide at 68° F.....	1.17
Still 5% Calcium Chloride at 68° F.....	1.06
Still Mineral Oils at 68° F.....	0.17 to 0.36
(Saybolt Viscosity 75 to 250)	
Still Vegetable Oils at 68° F.....	0.15 to 0.37
(Saybolt Viscosity 200 to 1500)	
Still Animal Oils at 68° F.....	0.19 to 0.35
(Saybolt Viscosity 130 to 270)	

Water—Water is the most convenient of all the quenching media. The quenching rate of water drops with the rise of temperature. Near the boiling point water has only about 10 per cent of its quenching power as compared to water at 68°F. This is possibly due to the vapor blanket formed, preventing effective heat dissipation.

Sodium Chloride Solutions—Sodium chloride solutions reduce the effect of vapor blanket, and are therefore more efficient quenching media than water. Ten per cent brine solution is often recommended but higher concentrations are to be avoided. It is always necessary to rinse the metal after quenching in brine solution so as to avoid corrosion.

Sodium Hydroxide Solutions—These solutions give a bright finish to steel after quenching and do not corrode the steel. Only solutions of low concentration are recommended. These solutions will irritate the skin and therefore require care in handling.

Oils—Oils have one-fifth to one-third of the cooling rate of water. They produce less distortion and less residual stress in steel, and therefore, are well adapted to complicated shapes and steels of high alloy contents.

Heat from hot metal renders vegetable and animal oils gummy and produces offensive odors. In most localities they are expensive. Mineral oils are generally used for heat-treating practice because of their lower cost and more stable nature than vegetable and animal oils.

In the selection of a quenching oil, several factors should be considered:

(1) The oil must give the proper cooling rate to produce the desired properties in the steel.

- (2) It must be reasonably stable.
- (3) It should be generally available and low in initial cost.
- (4) It should be chemically inactive with hot metal.
- (5) It should have a high flash point.

Steel after quenching, regardless of the medium used, should be drawn immediately after the quenching operation. There is great danger of cracking as long as the part contains the unrelieved quenching strains. It is recommended that the part be put in the drawing furnace before it has cooled to room temperature, as insurance against trouble of this nature.

The illustrations on pages 187, 188 and 189 show the reaction which occurs during the quenching operation in different media. They are reproduced by permission of the maker, Professor I. N. Zavarine, Department of Mining and Metallurgy, Massachusetts Institute of Technology, and "Metal Progress," published by the American Society for Metals.

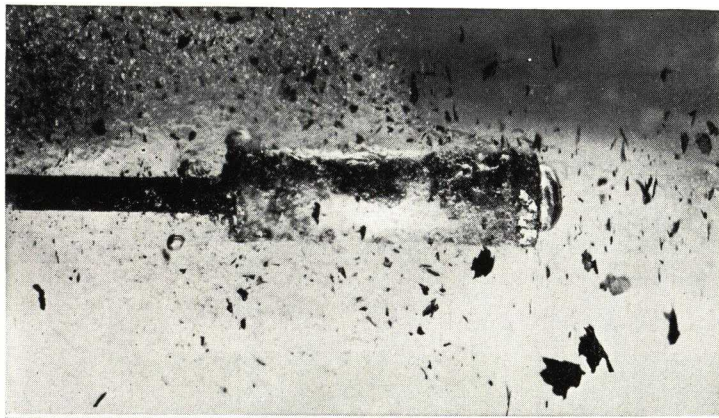
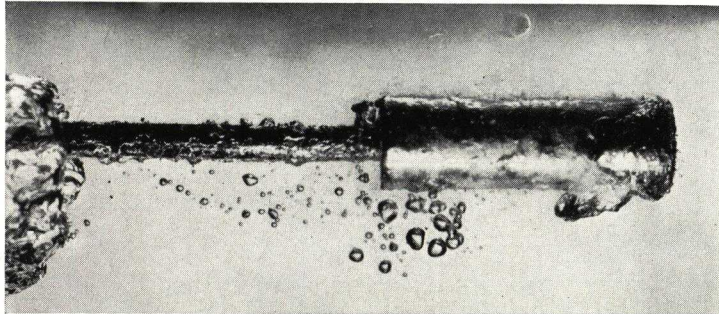
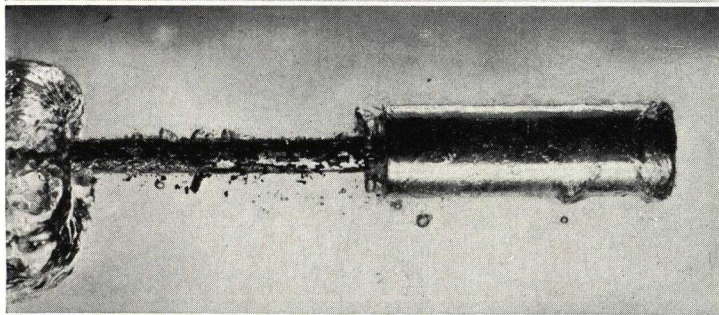
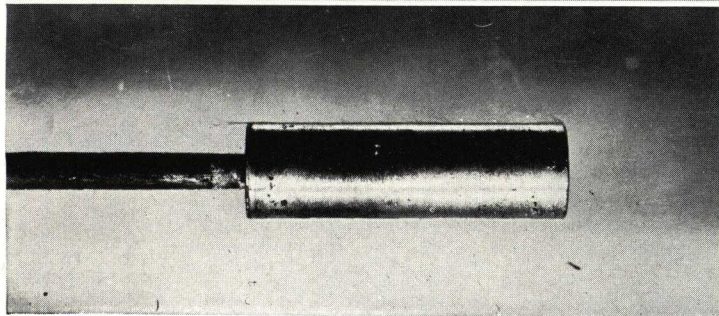
These photographs were made by a method of high speed photography developed by Professors Egerton and Germeshausen at the Massachusetts Institute of Technology. It consists of instantaneous illumination of the object by means of a spark of high intensity, which is produced by a discharge of an electrical condenser between two magnesium electrodes; the duration of the spark is estimated to be one millionth of a second, short enough to stop effectively all motion of the object being photographed.

The procedure in making the pictures was briefly as follows: a specimen $\frac{5}{8}$ in. diameter and 2 in. long, supported by a $\frac{1}{4}$ -in. rod, was heated in a vertical electric furnace located above the quenching bath. Guides were used to insure proper alignment of the specimen in the field covered by the photographic camera.

Briefly summarizing the results obtained, it is concluded that water and oil behave somewhat similar with respect to continuous moving envelopes of steam or oil vapor around the quenched pieces. The greater velocity of the brine or of caustic soda quench, as compared with water quenching, is due principally to the mechanical agitation of the quenching solution induced by the explosion of salt crystals.

BRINE QUENCHING

WATER QUENCHED CYLINDERS



Quenching complete in 5 seconds
Shown here for comparison

Start of 1550 degree F. quench

After start of quench

Two seconds after start of quench

Relatively quiet at start with thin film of steam moving in wave-like motion toward the top of specimen and a few steam bubbles given off. Air balloon rising is at top of picture. In two seconds action is violent enough to tear off scale.

BRINE QUENCHED CYLINDERS



Beginning of quench in 20 per cent solution of sodium chloride

The brine has just touched the hot surface of the specimen and a cloud is instantaneously formed. Fragments of scale are flying away, but there is no question that the main cloud consists of salt crystals which were precipitated on the surface of the metal in the steam envelope.

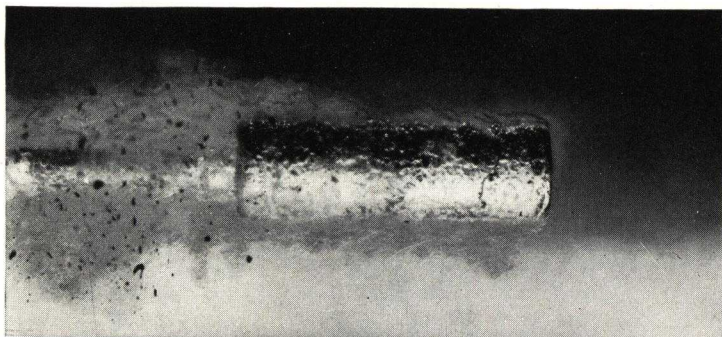


Beginning of quench in 5 per cent solution of sodium chloride

In a brine or caustic solution the action is quite distinctive. A cloud of salt crystals is thrown away from the hot metal with explosive violence. Finish of quench is shown at extreme left of page 187

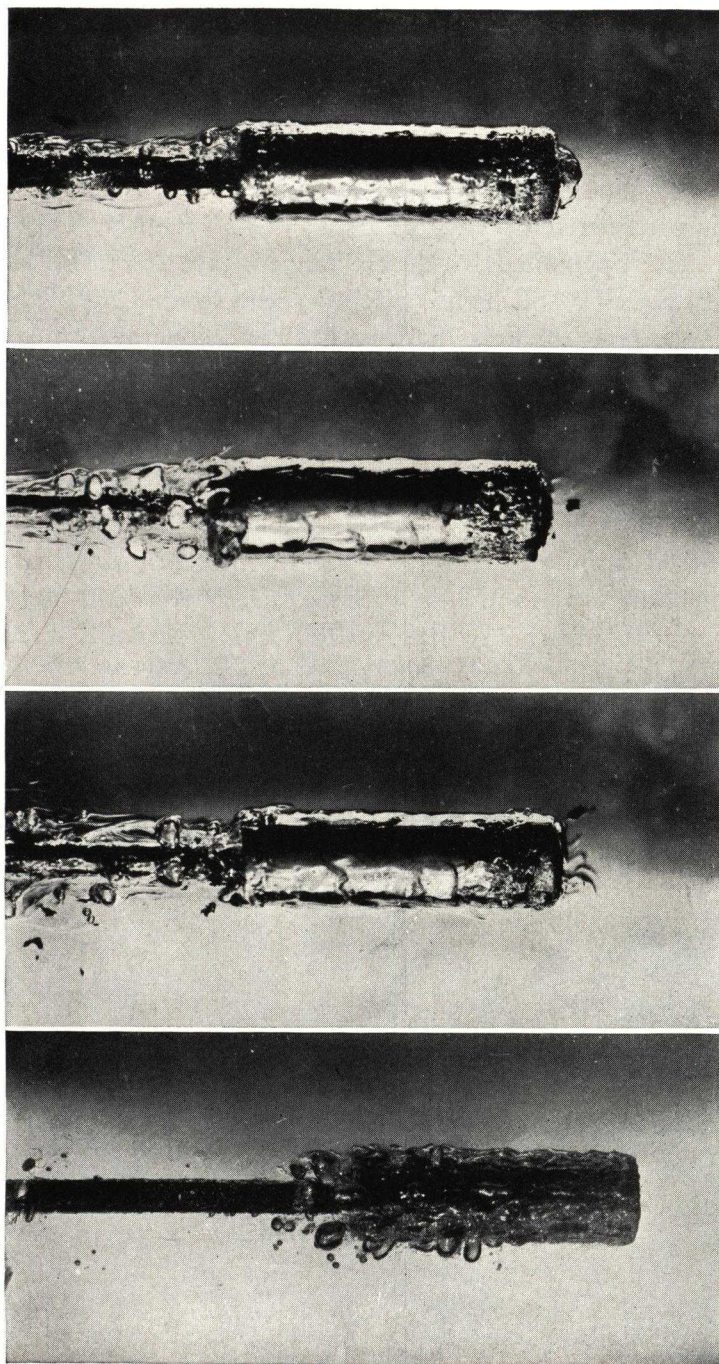


Two-step quench. Specimen retained in a position above the field of the photograph for an instant and then dropped to a lower position



Two-step quench. Specimen retained in the upper position one quarter second and photographed

OIL QUENCHED CYLINDERS



Five seconds after the beginning of quench in Russian oil

One second after beginning of quench in Russian oil

One-half second after the beginning of quench in Russian oil

Beginning of quench in transformer oil

Oil quench acts like water quenching at a more deliberate pace. Bubbles of oil vapor form quickly, and the vapor quickly forms a relatively thin layer with same wave-like motion as water quenching.

PYROMETERS

THE optical pyrometer principle is based on comparing and balancing luminous radiations. Optical pyrometers utilize the method of varying the brilliancy of a standard in comparison with the object until a visual balance is obtained. This type of pyrometer is used for temperatures 1400° F. and higher. Typical applications are: open hearth and electric furnace steel and slag temperatures, tapping and teeming temperatures; soaking pit and heating furnace temperatures; rolling mill and forging temperatures, molten cast iron temperatures; coke oven flue temperatures, etc.

Radiation pyrometers, of which there are two classes, are virtually reflecting telescopes: those which measure, as heat, the total radiation falling upon the receiving body of the instrument; and those based upon the fact that the intensity of light from incandescent bodies varies in a definite manner as the temperature changes. Applications are: rolling mill, heating furnace, refractory temperatures, etc.

Thermocouple pyrometers are of the contact, recording and automatic control types. The measurement of the electromotive forces developed in a thermocouple is used to indicate temperatures. An increase in temperature results in an increase of electromotive force developed. The thermocouple consists of two parallel electrical conductors of dissimilar metal, joined at one end but otherwise insulated from each other. Materials commonly used for thermocouples are: platinum, platinum-rhodium, iron-constantan, chromel-alumel.

The contact thermocouple pyrometer is used for reading temperatures of steel having no color (under approximately 1000° F.). While the temperatures obtained may not be representative of the actual temperature, they are helpful for certain uses as a comparison or guide.

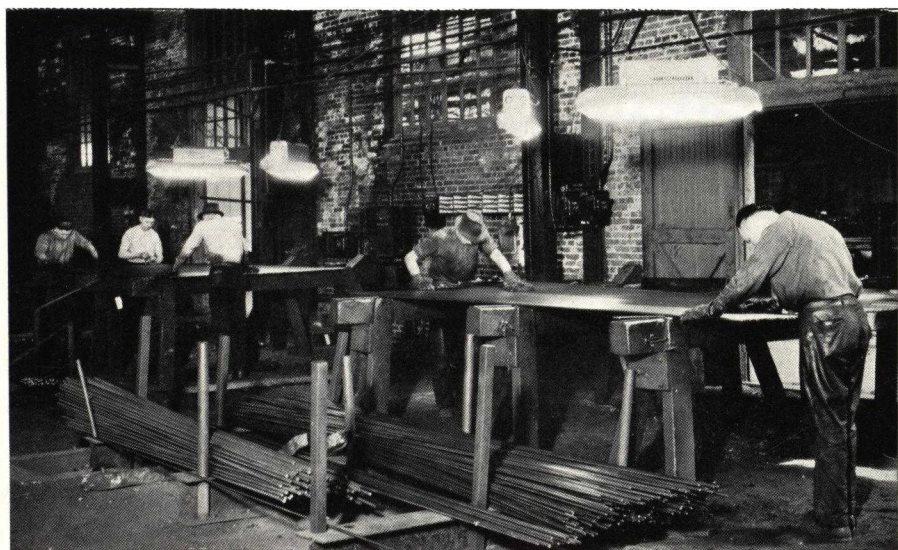
The recording and automatic control pyrometer is extensively used in heat-treatment shops. All heat-treatment furnace temperatures can be controlled by automatic recorders to assist in obtaining uniformity. Other operations controlled by automatic

recorders are: blast-furnace operations, open hearth furnaces, heating furnaces, core drying ovens, etc.

The immersion thermocouple pyrometers consist of a thermocouple having a suitable protection tube. The thermocouple immersed in molten metal develops an electromotive force and is recorded as stated above.

The photo-electric tube, often referred to as the electric eye, is a vacuum tube or an inert-gas-filled tube by means of which light can be made to control the flow of electromotive force. In general, it is comparable in operation to the radiation pyrometer. The application of the electric eye can be divided into three groups, namely: controlling operating units, as starting and stopping motors, flying shears, etc.; indicating devices, and pyrometers. Its uses as a pyrometer are similar to those of the radiation pyrometer.

In using pyrometers, it must be remembered that any type of instrument records only the temperature of the part at which the apparatus is sighted, or the temperature where the thermocouple is located. Care must therefore be exercised to insure getting representative temperature readings.



Inspecting cold-drawn bars

LIQUID HEATING BATHS

IMMERSION heating has many distinct advantages which make it desirable for routine hardening and tempering operations. It makes possible rapid and uniform heating of parts, prevents scale, thus eliminating subsequent cleaning operations, and helps to prevent warping or cracking of intricate sections.

Three types of heating baths are in common use and may be classified as follows:

	Temperature Range
No. 1—Oil	0 to 600 degrees F.
No. 2—Lead	650 to 1600 degrees F.
No. 3—Salts	300 to 2400 degrees F.

Oil baths are used for low temperature drawing operations where it is not necessary to exceed 600 degrees F. As this temperature is approached, increasing difficulty will be encountered in controlling the bath and at the same time a gum or coke deposit is apt to form on the work. This deposit can be removed only by hot caustic or kerosene.

It must be remembered that the use of oil baths at high temperatures involves a fire hazard which can be avoided by replacing the bath with one using low temperature salts.

Lead baths have a high heating rate and although they are used mainly for the drawing of high speed steel, they can be employed for other heating operations up to 1600 degrees F. Since lead oxidizes rapidly, it is necessary to keep the bath well protected by charcoal, molten salts, etc., when working at high temperatures to prevent the formation of scum or dross, which may cling to the work and retard any subsequent quenching operation.

Salt baths are used to cover a wide range of temperatures. With the exception of the extremely low temperatures it will usually be found more convenient to either make up or buy ready prepared salts for use within the different hardening or drawing ranges. These baths are easily controlled at the desired temperatures and effectively prevent scaling.

COLOR CHARTS

HEAT COLORS

The heat colors on the following page are reproductions of the colors observed on pieces of 3140 steel as seen through peep holes in enclosed furnaces and during average daylight conditions. The colors shown are approximately correct for these conditions. There are, however, many factors which enter into the visual appearance of the heated steel such as conditions of artificial or natural light, the character of the scale on the steel, the amount of radiated light within the furnace, the emissivity or tendency of steel to radiate or emit light, etc., and all these affect the apparent colors.

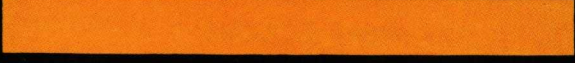
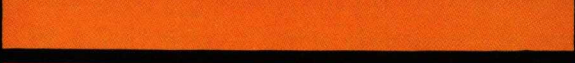
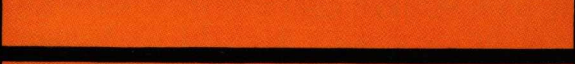
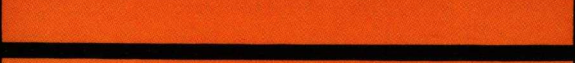
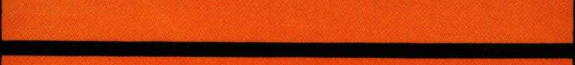
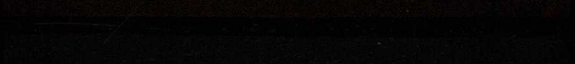
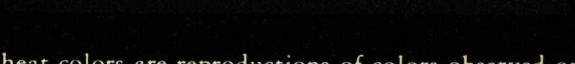
It is impossible to register by printed color the brilliance or intensity of the color of the metal, which in practical application is as valuable as the color itself.

TEMPER COLORS

The temper colors shown on page 195 were observed on drawing 1095 steel to the temperatures indicated.

BETHLEHEM STEEL COMPANY

HEAT COLORS

Degrees Fahrenheit		Degrees Centigrade
2500		1371
2400		1316
2300		1260
2200		1204
2100		1149
2000		1093
1900		1038
1800		982
1700		927
1600		871
1500		816
1400		760
1300		704
1200		649
1100		593
1000		538

The above heat colors are reproductions of colors observed on pieces of 31-40 steel as seen through peep holes in enclosed furnaces and during average daylight conditions.

BETHLEHEM STEEL COMPANY

TEMPER COLORS

Degrees Fahrenheit		Degrees Centigrade
700		371
660		349
620		327
580		304
540		282
500		260
460		238
420		216
380		193

The above temper colors were observed on tempering 0.95 per cent carbon steel at the temperatures indicated.

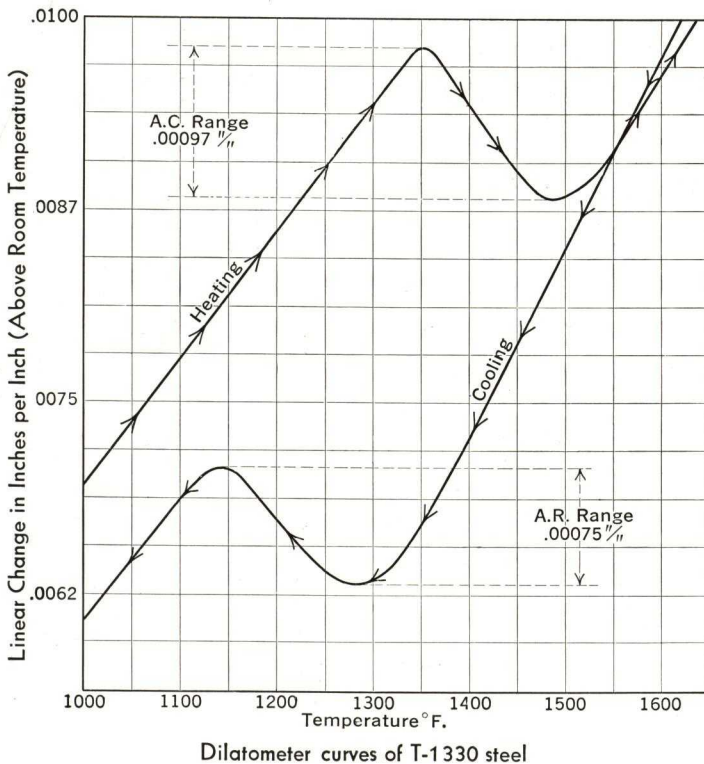


Spark, spot and bench testing for chemical identification of the bars and close surface inspection.

HEATING STEEL

IN THE process of heating steel, various dangers are encountered which must be avoided. In addition to cracking, which generally is given the first thought, we also have overheating or burning and excessive decarburization to consider.

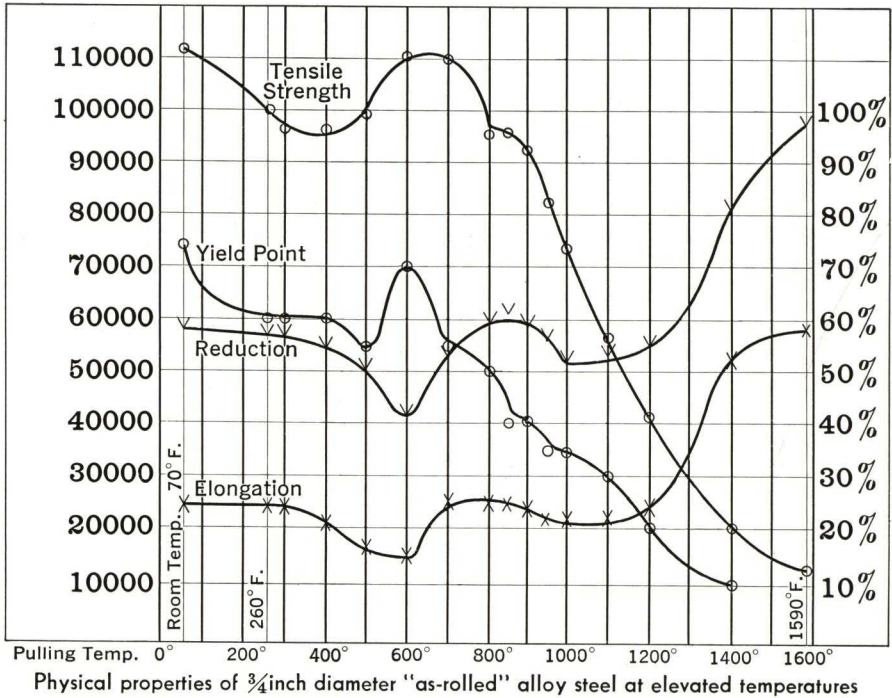
Steel, on heating up to its critical point, follows the coefficient of expansion curves in change of volume. When passing through the critical or transformation ranges the volume change does not follow the coefficient of expansion, but radically changes from



Dilatometer curves of T-1330 steel

expansion to contraction during that period. As soon as the ranges have been passed, the steel again expands.

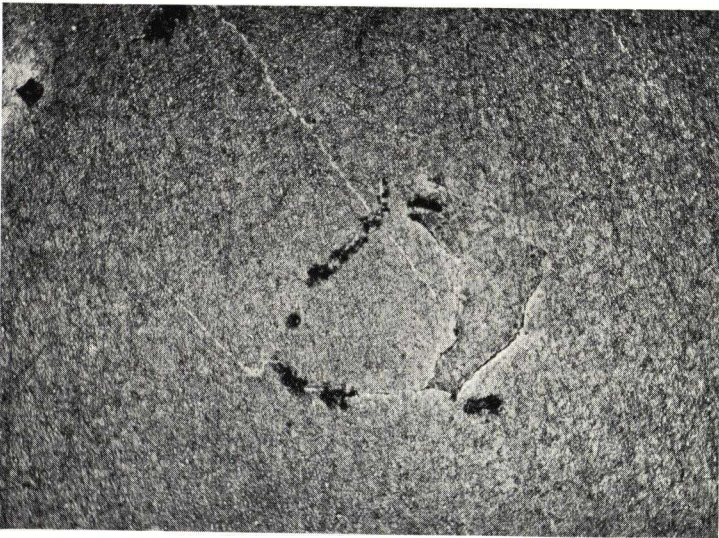
It must be remembered that steel at elevated temperature does not possess its normal strength. The strength of steel on being heated changes continually up to the plastic state. As shown on the curves, as the temperature increases above normal, the strength decreases until about 600° to 800° F. is reached, where the "blue brittle range" occurs. At this point the strength increases, often going as high as the strength at normal temperature, and ductility decreases. As the temperature increases beyond the "blue brittle range" the strength rapidly decreases. At 1600° F. steel will show 10,000 to 20,000 pounds per square inch tensile strength, in the grades of steel covered by this publication.



A common source of trouble when heating steel is cracking. Cracks are caused by heating or cooling too rapidly or not uniformly and are the result of non-uniform volume changes in the steel, which set up stresses higher than the strength of the part. Steel becomes increasingly more prone to this type of trouble as the percentage of hardening elements increases.



Photograph of fracture of overheated steel in hardened condition. Enlarged $2\frac{3}{4}$ times



Micrograph of same steel at 100 diameters. Etched with Stead's reagent, showing porosity and segregation around crystal

The iron-carbon diagram shows the increasing danger of overheating steel as the carbon content increases. The introduction of alloys into steel does not change this situation. Not only must the average temperature of the heating furnace be regulated, but local overheating, such as is caused by direct impingement of the flame against a piece of steel, must be avoided.

The degree of overheating of steel depends on the temperature, atmosphere, and the time the part was kept above the safe heating range. The surface of burnt steel often contains a network of fine cracks. When the abuse was not severe enough to cause burning but when overheating occurred, it is hard to detect unless the microscope is used to determine how badly the structure has been broken down.

Overheating has a marked effect on the physical properties of steel, the degree of deterioration, of course, depending on the amount of abuse; until finally, in the case of badly burnt steel, there is no strength, and the piece will practically fall apart.

Decarburization occurs when a piece of steel is heated to any temperature above the scaling point in the usual commercial heating furnace. It takes place, but to a lesser degree, under the so-called reducing atmospheric conditions when a smoky flame is used. To eliminate decarburization requires expensive and rather elaborate equipment for the usual commercial heating furnace.

The degree of decarburization is a function of both temperature and time. It is caused by the carbon in the skin of the steel, when heated, chemically uniting with oxygen. Carbon in hot steel migrates, that from the layer of steel under the skin passing to the lower-carbon or carbon-free skin. This action is progressive so long as the steel is kept under the conditions which cause decarburization, and continually increases the depth of the lower-carbon case.

In a low-carbon steel the reaction is not severe because it lacks the carbon content to support the migration. As the carbon content increases, the severity of the reaction likewise increases. It is therefore necessary to exercise more care in heating the higher carbon steels.

Fortunately, in most cases, machining or grinding removes the decarburized surface and its deleterious effects on parts where hard surfaces are necessary for wear or abrasion.

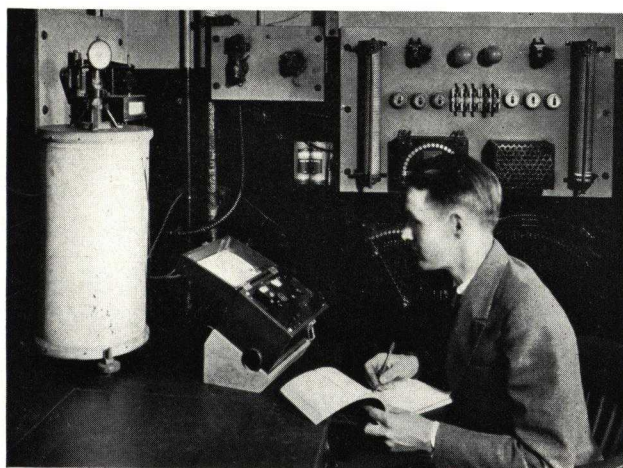
SOFTENING AND MELTING POINTS OF VARIOUS REFRACTORIES

Material	Initial Softening Temp.	Melting Temp.
Clay Brick—1st quality.....	2560°–2600° F.	3100° F. Plus
Clay Brick—2nd quality.....	2400° F.	3000° F.
Sleeves (Clay)—(highest quality).....	2500°–2550° F.	3100° F.
Nozzles (Clay)—(highest quality).....	2500°–2550° F.	3100° F. Plus
Sleeves and Nozzles—(regular grade).....	2250°–2300° F.	2900° F.
Graphite Stopper Heads.....	2775° F. Plus	.....
Ladle Brick.....	2200° F.	2675° F.
Chrome Brick.....	2650° F.	3700° F. Plus
Magnesite Brick.....	2650° F.	3800° F. Plus
Silica Brick.....	2600° F.	3137° F. Plus
Runner Brick (Bottom Pour).....	2560° F.	3100° F.
Quick-Set Magnesite (Bottom-Material).....	2550°–2750° F.	3675° F. Plus

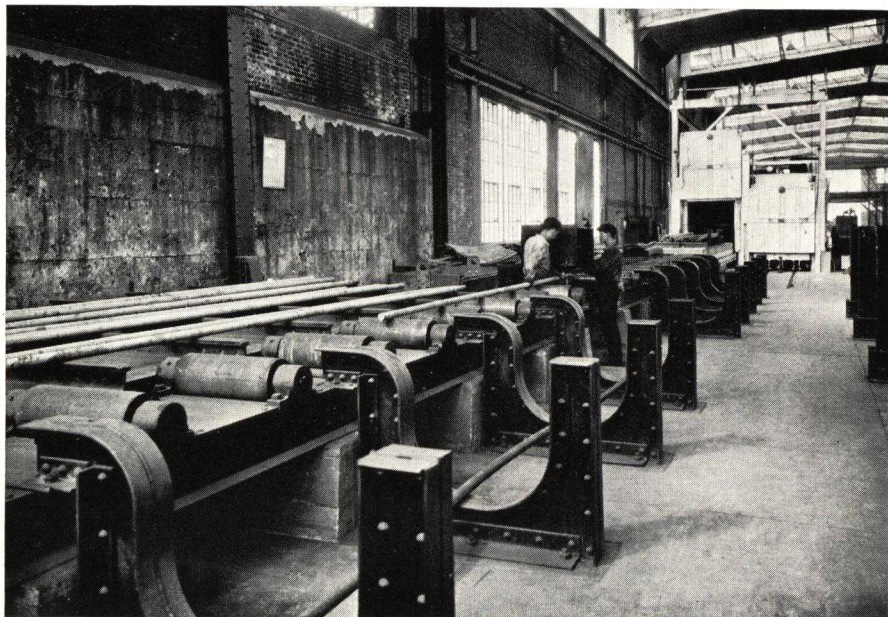
Note—Softening Temperatures shown above are for material with no load. When load is applied, softening occurs at lower temperatures.

Temperatures shown are actual for materials. Slag action such as is encountered in service will lower temperatures from 200° to 400° F.

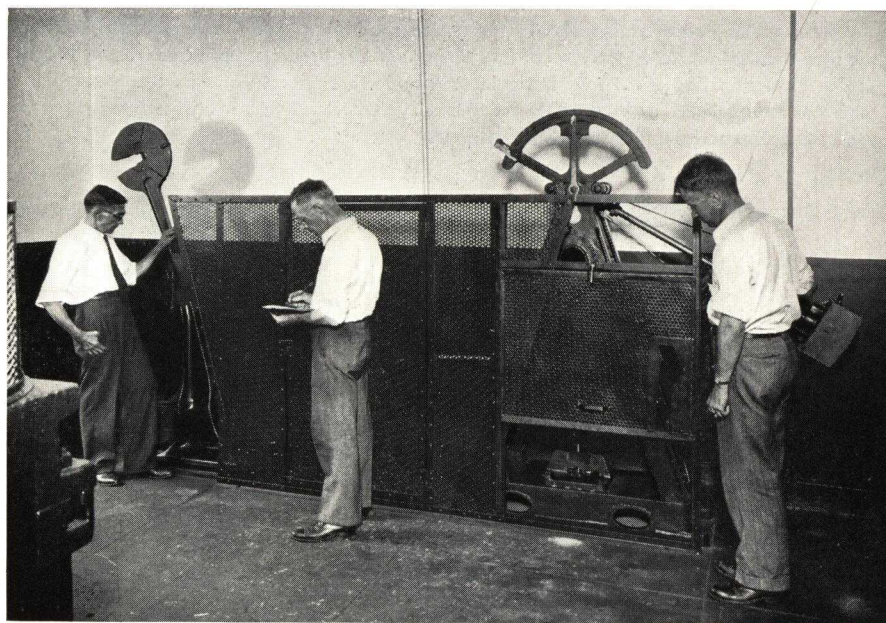
When making alloy steels, it is imperative that the highest quality refractories be used due to the time the steel is held in the furnace for refining and the higher temperatures required for some grades. Contamination of the steel in the ladle or mold through inferior refractory material is just as serious as dirt picked up by the steel due to carelessness. Bethlehem Alloy Steels are protected by purchasing refractories to very rigid specifications.



Dilatometer used for determining coefficients of expansion and critical ranges



Hardness testing, heat-treated bars



Impact testing

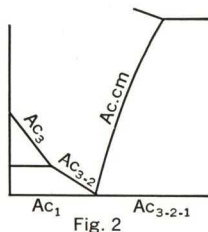
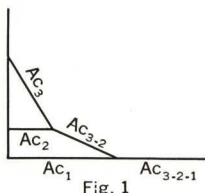
PART 5

**DEFINITION
OF
COMMON TERMS**

DEFINITION OF SOME COMMON TERMS USED IN THE STEEL INDUSTRY

(Reprinted mainly from American Society for Metals Handbook)

During recent years certain confusion has arisen in regard to the meaning of terms commonly used in heat treating. For instance, in one locality or trade any operation of heating and cooling which results in a softening of the material is being called annealing, whereas in other places "to anneal" means not primarily "to soften" but to heat above the critical temperature range and cool very slowly. Similar confusion as to meaning and application exists in regard to other terms, and as a result "annealing," "tempering," "normalizing," etc., are being used by different people to mean widely different things.



In any attempt accurately to define the terms commonly used in connection with heat treatment, the first and most important question to decide is: do the terms relate to the heat treatment operation itself, or to the results obtained by the treatment? In other words, is the term indicative of the structure or condition obtained, or of the operation performed?

After careful consideration, it appears most logical and most in keeping with present day usage to have the terms so defined that they shall mean definite operations and shall not be considered as referring to the resultant structure or general conditions.

By "critical temperature range," as used in the definitions, is meant the temperature range illustrated by the diagrams given in Figs. 1 and 2.

ACID BOTTOM AND LINING—The inner bottom and lining of a melting furnace composed of materials having an acid reaction. The materials may be sand, siliceous rock, or silica bricks.

ACID BRITTLINESS—The brittleness induced in steel, especially wire or sheet, when pickled in dilute acid for the purpose of removing scale. This brittleness is commonly attributed to the absorption of hydrogen.

ACID STEEL—Steel melted under a slag which has an acid reaction and in a furnace with an acid bottom and lining.

AGING—The term originally applied to the process or sometimes to the effects of allowing a metal to remain at ordinary temperatures. Heat treatment

at temperatures above normal for the purpose of accelerating changes of the type that might take place on aging at ordinary temperature is called "artificial aging," and sometimes merely "aging." When the changes taking place during artificial aging are due to the precipitation of some substance from solid solution the heat treatment may be called "precipitation treatment."

ALLOY—A material having metallic properties and consisting of two or more elements, of which at least one is a metal. It is considered by some that the elements must be completely miscible in the liquid state; others apply the term alloy even when liquid miscibility is only partial.

ALLOY ELEMENTS—Elements added for the purpose of improving properties.

ALPHA IRON—See the "Iron-Carbon Diagram" in Part 3.

AMORPHOUS—Non-crystalline.

ANNEALING—A heating and cooling operation of a material in the solid state, usually implying a relatively slow cooling.

Note—Annealing is a comprehensive term. The purpose of such a heat treatment may be:

- (a) To remove stresses.
- (b) To induce softness.
- (c) To alter ductility, toughness, electrical, magnetic, or other physical properties.
- (d) To refine the crystalline structure.
- (e) To remove gases.
- (f) To produce a definite microstructure.

In annealing, the temperature of the operation and the rate of cooling depend upon the material being heat treated and the purpose of the treatment.

Certain specific heat treatments coming under the comprehensive term "annealing" are:

A. Full Annealing—Heating iron base alloys above the critical temperature range, holding above that range for a proper period of time, followed by slow cooling through the range.

Note—The annealing temperature is generally about 100 degrees Fahr. above the upper limit of the critical temperature range, and the time of holding is usually not less than one hour for each inch of section of the heaviest objects being treated. The objects being treated are ordinarily allowed to cool slowly in the furnace. They may, however, be removed from the furnace, and cooled in some medium that will prolong the time of cooling as compared to unrestricted cooling in the air.

B. Process Annealing—Heating iron base alloys to a temperature below or close to the lower limit of the critical temperature range, followed by cooling as desired.

Note—This heat treatment is commonly applied in the sheet and wire industries and the temperatures generally used are from 1020 to 1200 degrees Fahr.

C. Normalizing—Heating iron base alloys to above the critical temperature range, followed by cooling fairly rapidly to below that range.

Note—Normalizing is rarely practiced with hypereutectoid steels because of the coarsening of the grain and the tendency to crystallize cementite at grain boundaries or in needles. However, it may sometimes be necessary to normalize these steels by heating them above the A_{cm} line of the iron-carbon diagram shown in Fig. 2.

D. Patenting—Heating iron base alloys above the critical temperature range, followed by cooling to below that range in air or in molten lead which is maintained at a temperature of about 700 degrees Fahr.

Note—This treatment is usually applied in the wire industry as a finishing treatment or, especially, in the case of eutectoid steel, as a treatment previous to further wire drawing. Its purpose is to produce a sorbitic structure.

E. Spheroidizing—Prolonged heating of iron base alloys at a temperature, in the neighborhood of, but generally slightly below, the critical temperature range, usually followed by relatively slow cooling.

Note—(a) In the case of small objects of high-carbon steels, the spheroidizing result is achieved more rapidly by prolonged heating to temperatures alternately within and slightly below the critical temperature range.

(b) The object of this heat treatment is to produce a globular condition of the carbide.

F. Tempering (also termed Drawing)—Reheating iron base alloys, after hardening, to some temperature below the critical temperature range, followed by any desired rate of cooling.

Note—(a) Although the terms "tempering" and "drawing" are practically synonymous as used in commercial practice, the term "tempering" is preferred.

(b) Tempering, meaning the operation of hardening followed by reheating, is a usage which is illogical and confusing in the present state of the art of heat treating and should be discouraged.

G. Malleableizing—Malleableizing is a type of annealing operation with slow cooling whereby the combined carbon in white cast iron is transformed to temper carbon and in some cases the carbon is entirely removed from the iron.

Note—Temper carbon is free carbon in the form of rounded nodules made up of an aggregate of minute crystals.

H. Graphitizing—Graphitizing is a type of annealing for gray cast iron whereby some or all of the combined carbon is transformed to free or uncombined carbon.

AUSTENITE—See the "Iron-Carbon Diagram" in Part 3.

BANDED STRUCTURE—A segregated structure of parallel bands which run in the direction of working.

BARK—The decarburized skin or layer just beneath the scale.

BASIC BOTTOM AND LINING—The inner lining and bottom of a melting furnace composed of materials having a basic reaction. The materials may be crushed burnt dolomite, magnesite, magnesite bricks, or basic slag.

BASIC STEEL—Steel melted under a slag having a basic reaction and in a furnace with a basic bottom and lining.

BESSEMER PROCESS—A process for making steel by blowing air through molten pig iron contained in a suitable vessel, thus removing the impurities by oxidation.

BETA IRON—See the "Iron-Carbon Diagram" in Part 3.

BILLET—A semi-finished rolled ingot of rectangular cross section or nearly so. In general the term "billet" is used when the cross section ranges from 4 up to 36 square inches, the width always being less than twice the thickness. Small sizes are usually classed as bars or "small billets." The term "bloom" is properly used when the cross section is greater than about 36 square inches, but this distinction is not universally observed.

BILLET MILL—See *blooming mill*.

BINARY ALLOY—An alloy containing two principal elements.

BLACK ANNEALING—A process of annealing sheets in boxes, prior to tinning, which imparts a black color to the surface of the product. The term is

also used in the manufacture of other products when no special precautions are needed to insure the annealed product being free from scale or discoloration.

BLAST FURNACE—A shaft furnace supplied with air blast, usually hot, for producing pig iron by reducing iron ore. The furnace is continuous in operation, the raw materials (iron ore, coke, and limestone) are charged at the top, and the molten pig iron and slag are collected at the bottom and are tapped out at intervals.

BLISTER—A defect in metal produced by gas bubbles either on the surface or formed beneath the surface while the metal is hot or plastic. Very fine blisters are called pinhead or pepper blisters.

BLISTER BAR—Wrought iron bars impregnated with carbon and used in the manufacture of crucible steel. Also called blister steel.

BLOOM—See *billet*.

BLOOMING MILL—A mill used to reduce ingots to blooms, billets, slabs or sheet bars. Depending upon the product, the mill is called a blooming mill (cogging mill in England), a billet mill, or a slabbing mill.

BLOWHOLE—A hole produced during the solidification of metal by evolved gas which, in failing to escape, is held in little pockets.

BLUE ANNEALING—A process of annealing sheets after rolling. The sheets, if fairly heavy, are allowed to cool slowly after the hot rolling; if of lighter gage, as is usually the case, they are passed singly through an open furnace where they are heated to the proper temperature for the annealing operation. As the name indicates, they have a bluish-black appearance.

BLUE BRITTLINESS—Brittleness occurring in steel when in the temperature range of 400 to 700 degrees Fahr., or when cold after being worked within this temperature range.

BOX ANNEALING—Softening steel by heating it in a suitable closed metal box or pot to protect it from oxidation; also called closed annealing or pot annealing.

BRIGHT ANNEALED WIRE—Wire carefully annealed in closed pots, often with reducing gases, to keep surface oxidation to a minimum.

BURNING—The heating of a metal to temperatures sufficiently close to the melting point to cause permanent injury. Such injury may be caused by the melting of the more fusible constituents, by the penetration of gases such as oxygen into the metal with consequent reactions, or perhaps by the segregation of elements already present in the metal.

CARBON FREE—Metals and alloys which are practically free from carbon.

CARBON STEEL—Steel which owes its properties chiefly to various percentages of carbon without substantial amounts of other alloying elements; also known as ordinary steel or straight carbon steel.

CARBONIZATION—Coking or driving off the volatile matter from fuels such as coal and wood. (Carbonizing should not be confused with "carburizing" q.v.)

CARBURIZING (CEMENTATION)—Adding carbon to iron base alloys by heating the metal below its melting point in contact with carbonaceous solids, liquids or gases.

Note—The term "carbonizing" used in this sense is incorrect and its use should be discouraged.

CASE—That portion of a carburized iron base alloy article in which the carbon content has been substantially increased.

CASE HARDENING—Carburizing, and subsequently hardening by suitable heat treatment, all or part of the surface portions of a piece of iron base alloy.

CAST STEEL—Any object made by pouring molten steel into molds.

CASTING STRAINS—Strains accompanied by internal stresses resulting from the cooling of a casting.

CEMENTITE—See the "Iron-Carbon Diagram" in Part 3.

CHILL CAST PIG—Pig iron cast into metal molds or chills. If a machine is used the product is known as machine cast pig.

CHIPPING—One method of removing seams and other surface defects from partially worked material so that the defects will not be worked into the finished product. If the defects are removed by means of a gas torch the term "deseaming" or "scarfing" is used.

CLEAVAGE PLANE—Crystals possess the property of breaking more readily in one or more directions than in others. The planes of easy rupture are called cleavage planes.

COGGING—Rolling or forging ingots to reduce them to blooms.

COGGING HAMMER—A forging hammer used to reduce ingots to blooms.

COGGING MILL—See *blooming mill*.

COLD ROLLING—See *cold working*.

COLD SHUT—(1) A portion of the surface of a metal product which is not integral with the main mass. This usually results from rolling or forging into the product a separate or partially separate piece of metal, such as that which spatters on the surface of an ingot, or mechanical projections. (2) The freezing over of the top surface of an ingot before the mold has been filled, due to an interruption of the stream of metal.

COLD WORKING—Permanent deformation of a metal below its recrystallization temperature.

COMBINED CARBON—All of the carbon in iron or steel which is not in the form of graphite.

CORE—That portion of a carburized iron base alloy article in which the carbon content has not been substantially increased.

Also a body of sand or other material placed in a mold to produce a cavity in a casting.

Note—The terms "case" and "core" refer to both case hardening and carburizing.

CORE STRUCTURE—A structure having its interior or core of different structure or material from the exterior.

CRITICAL POINTS—See the "Iron-Carbon Diagram" in Part 3.

CRITICAL RANGE—See *critical points*.

CRITICAL TEMPERATURE—See *critical points*.

CROP—The end or ends of a rolled or forged product containing the pipe or other defects which are cut off and discarded; also termed "crop end" and "discard."

CUP FRACTURE—The form of fracture of a tensile test specimen when the exterior portion is extended and the interior relatively depressed, so that it looks like a cup, as the name implies. When only a portion of the exterior is extended the terms "half cupped" and "quarter cupped" are used, as the case may be.

CUPPING—A defect in wire which causes it to break with a cup fracture.

CYANIDING—Surface hardening of an iron base alloy article or portion of it by heating at a suitable temperature in contact with a cyanide salt, followed by quenching.

DECALESCENCE—The absorption of heat which occurs when steel is heated through the Ac_1 point.

DECARBURIZATION—The removal of carbon (usually refers to the surface of solid steel).

DENDRITE—A crystal formed during solidification having many branches and a tree-like pattern; also termed "pine tree" and "fir tree" crystals.

DIFFERENTIAL HEATING—Heating conducted in such a way that various portions of an object attain different temperatures so that upon cooling different properties are produced.

DISCARD—See *crop*.

DISSOLVED CARBON—Carbon in solution in either the liquid or solid state.

DRAWING BACK—See *tempering*, under *annealing*.

ENDURANCE LIMIT—The maximum stress to which material may be subjected an indefinitely large number of times without causing failure.

EQUILIBRIUM—See the "Iron-Carbon Diagram" in Part 3.

EUTECTIC—An alloy having the lowest melting point possible with the given components.

EUTECTOID STEEL—Steel made up exclusively of pearlite.

EXFOLIATION—The spalling or flaking off of the outer layer of an object.

FATIGUE—See comments under spring steels and endurance strength of steels.

FERRITE—See the "Iron-Carbon Diagram" in Part 3.

FERRITE GHOST—A faint band of ferrite.

FERRO ALLOYS—An alloy of iron with a sufficient amount of some element or elements, such as manganese, chromium, or vanadium, used as a means of introducing these elements into steel.

FIBER—A characteristic of wrought metal manifested by a fibrous or woody appearance of fractures and indicating directional properties. Fiber is due chiefly to the extension in the direction of working of the constituents of the metal, both metallic and nonmetallic.

FIBER STRESS—Local unit stress at a point or line on a section over which stress is not uniform, such as the cross section of a beam under a bending load.

FIN—See *flash*.

FINISHED STEEL—Steel which is ready for the market without any further work or treatment. Blooms, billets, slabs, and wire rods are termed semi-finished.

FINISHING TEMPERATURE—The temperature at which hot mechanical working of metal is completed.

FIR TREE CRYSTAL—See *dendrite*.

FLAKES—Portions of a steel fracture with a bright, scaly appearance.

FLASH—A thin fin of metal formed at the sides of a forging where a small portion of the metal is forced out between the edges of the forging dies.

FORGING STRAINS—Strains resulting from forging or from cooling from the forging temperature.

FRACTURE—The irregular surface produced when a piece of metal is ruptured or broken.

FRACTURE TEST—Breaking a piece of metal for the purpose of examining the fractured surface to determine the structure or carbon content of the metal or the presence of internal defects.

FREE FERRITE—Ferrite which is structurally separate and distinct.

FULL ANNEALING—See *annealing*.

FUSIBLE ALLOYS—A group of nonferrous alloys which melt at very low temperatures. They usually consist of bismuth, lead, tin, etc. in various proportions, and iron only as an impurity.

GAMMA IRON—A crystal form of iron (face-centered cubic) see the "Iron-Carbon Diagram" in Part 3.

GHOST, GHOST LINES, OR GHOST STRUCTURE—See *ferrite ghost*.

GRAINS—Crystals in metals.

GRAIN GROWTH—An increase in the grain size of metal.

GRANULAR PEARLITE (ALSO GLOBULAR PEARLITE)—A structure formed by holding steel for some time at a temperature just below the critical, causing the cementite and ferrite in the pearlite to separate into globules.

GRANULATION—The formation of grains immediately upon solidification. The region in which it occurs is known as the granulation range or zone.

GRAPHITIZING—See *annealing*.

HAIR SEAM—See *seam*.

HARDENING—Heating and quenching certain iron base alloys from a temperature either within or above the critical temperature range.

HEAT TINTING—Heating a polished specimen in air after a brief preliminary treatment with dilute acid for the purpose of developing the structure by oxidizing or otherwise affecting the different constituents.

HEAT TREATMENT—An operation, or combination of operations, involving the heating and cooling of a metal or alloy in the solid state for the purpose of obtaining certain desirable conditions or properties.

Note—Heating and cooling for the sole purpose of mechanical working are excluded from the meaning of this definition.

HOT SHORTNESS—Brittleness in metal when hot.

HOT TOP—See *sinkhead*.

HOT WORKING—The mechanical working of metal above the recrystallization temperature.

HYPEREUTECTOID STEEL—A steel containing more than the eutectoid percentage of carbon (see *eutectoid*).

HYPO-EUTECTOID STEEL—A steel containing less than the eutectoid percentage of carbon; also see *eutectoid*.

IMPACT TEST—A test in which one or more blows are suddenly applied to a specimen. The results are usually expressed in terms of energy absorbed or number of blows (of a given intensity) required to break the specimen.

INCLUSIONS—Particles of slag and dirt occurring in metal which were mechanically held during solidification.

INGOT—A special kind of casting for subsequent rolling or forging.

INGOT IRON—An open hearth iron very low in carbon, manganese, and other impurities.

KILLED STEEL (ALSO DEAD)—Molten steel which has been held in a ladle, furnace, or crucible (and usually treated with aluminum, silicon, or manganese) until no more gas is evolved and the metal is perfectly quiet.

LAP—A surface defect appearing as a seam caused from folding over hot metal, fins, or sharp corners and then rolling or forging, but not welding, them into the surface.

LAP WELD—In making some tubes or pipe the edges of the skelp are beveled or scarfed so that when they are overlapped they can be welded together. The product is known as lap weld or lap welded pipe.

LUTE—A mixture of fireclay used to seal up cracks between crucible and cover or between annealing box and cover to make a gas-tight joint when heat is to be applied; also applied to the operation.

MACROSCOPIC—Visible either with the naked eye or under low magnifications (up to about 10 diameters).

MACROSTRUCTURE—The structure and internal condition of metals as revealed on a ground or polished (and sometimes etched) sample, by either the naked eye or under low magnifications (up to about 10 diameters).

MALLEABLEIZING—See *annealing*.

MARTENSITE—A microconstituent or structure in hardened steel characterized by an acicular or needle-like pattern. It has the maximum hardness of any of the decomposition products of austenite.

Note—It is believed by some that martensite consists of fine grained ferrite containing carbon in solution. On aging or tempering, cementite is precipitated, at first in submicroscopic form, but the structure may still retain its martensitic pattern.

MATRIX—The ground mass or principal substance in which a constituent is embedded.

MECHANICAL WORKING—Subjecting metal to pressure exerted by rolls, presses, or hammers, to change its form, or to affect the structure and therefore the physical properties.

MODULUS OF ELASTICITY—The ratio, within the limits of elasticity, of the stress to the corresponding strain. The stress in pounds per square inch is divided by the elongation in fractions of an inch for each inch of the original gage length of the specimen.

NETWORK STRUCTURE—A structure in which the grains or crystals of one constituent are partially or entirely surrounded with envelopes of another constituent. The appearance of an etched section through the crystals is that of network.

NEUMANN BANDS—Parallel lines or narrow bands running across crystalline grains of metal. The lines or bands undoubtedly indicate mechanical twins. Neumann bands are generally produced by a sudden deformation of the metal such as would result from shock, impact, or explosion.

NITRIDING—Adding nitrogen in iron base alloys by heating the metal in contact with ammonia gas or other suitable nitrogenous material.

Note—Nitriding is conducted at a temperature below the iron-carbon critical temperature range and produces surface hardening of the metal without quenching. See article on Nitriding in this book.

NORMALIZING—See *annealing*.

OVERHEATING—Heating to such high temperatures that the grains have become coarse, thus impairing the properties of the metal.

PATENTING—See *annealing*.

PEARLITE—See the "Iron-Carbon Diagram" in Part 3.

PERMANENT MOLD—A metal mold which is used repeatedly for the production of many castings of the same form. Not commonly applied to ingot molds.

PERMANENT SET—Permanent deformation.

PHOSPHORUS BANDING—A faint band of metal containing phosphide segregations.

PIERCING—Producing a hole in metal by forcing a pointed instrument through it. Usually refers to making steel tubes from solid steel bars.

PIG IRON—The iron product of the blast furnace.

PINE TREE CRYSTALS—See *dendrite*.

PINHEAD BLISTER—See *blister*.

PIPE—A cavity formed in metal (especially ingots) during the solidification of the last portion of liquid metal. Contraction of the metal causes this cavity or pipe.

PIT—A depression in the surface of metal.

POT ANNEALING—See *box annealing*.

PROCESS ANNEALING—See *annealing*.

QUATERNARY ALLOY—An alloy containing four principal elements.

QUENCHING—Rapid cooling by immersion. Immersion may be in liquids, gases, or solids.

RECALESCENCE—The liberation of heat when steel is cooling through the A_{r1} point.

RED SHORTNESS—Brittleness in steel when it is red hot.

REFINING TEMPERATURE OR HEAT—A temperature employed in heat treatment to refine the structure, in particular, the grain size. Usually just above A_{c3} in steel.

REGENERATIVE QUENCHING—A double quenching of carburized objects to refine the case and core. The first quench is from a high temperature to refine the core and the second quench is from a lower temperature to further refine the core and harden the case.

RIMMED STEEL—A low-carbon steel which (a) is effervescent when cast and during a considerable part of its solidification; (b) neither rises nor falls in the mold to any marked extent; (c) when completely solidified has no pipe but blowholes both centrally located and deep seated below the surface; (d) has been cleansed from some of the impurities and dirt because of their rising to the top during the agitation of the molten metal by the escaping gases; and (e) has a cross section divided into three fairly well defined zones: (1) a very clean thin outer layer of nearly the same chemical composition as when poured; (2) a central portion; and (3) an intermediate portion. The three zones are positively and negatively segregated with respect to metalloids.

Note—The term "rimmed" comes from the fact that during the gradual freezing inwards from the sides the molten portion at the top of the ingot becomes smaller and smaller and is said to "rim in" until finally the whole top is solidified.

SCAB (SCABBY)—A rough projection on a casting caused by the mold breaking or being washed by the molten metal; or occurring where the skin from a blowhole has partly burned away and is not welded.

SEAM—A crack on the surface of metal which has been closed but not welded up; usually produced by blowholes which have become oxidized. If very fine, a seam may be called a hair crack or hair seam; also see cold shut and lap.

SECONDARY HARDENING—Hardness developed by tempering high alloy steels.

SELF HARDENING STEEL—Alloy tool steel that becomes sufficiently hard by cooling in air (sometimes an air blast is employed) and whose cutting edges remain practically intact at temperatures approaching a visible red.

SEMI-FINISHED—See *finished steel*.

SEMI-STEEL—Castings produced by melting, usually in a cupola, about one-third to one-fifth by weight of wrought iron or soft steel scrap with cast iron.

SHORTNESS—Brittleness in metal.

SILKY FRACTURE—A steel fracture having a very smooth, fine grain, or silky appearance.

SINKHEAD OR HOT TOP—A heat-insulated reservoir for excess metal on top of an ingot mold which feeds the shrinkage of the ingot proper.

SKELP—A plate of steel of wrought iron from which pipe or tubing is made. This is done by rolling the skelp up longitudinally into shape and welding or riveting the edges together.

SLAB—A rectangular piece of steel which is to be rolled down into plates. It may be considered as very thick semi-finished plate.

SLABBING MILL—A heavy plate mill usually of the two-high, universal type.

SLIP BANDS—A series of parallel lines running across a crystalline grain. Slip bands are formed when the elastic limit is passed by one layer or portion of the crystal slipping over another portion along a plane, known as the slip plane.

SLIP PLANE—See *slip bands*.

SOAKING—Holding steel at a temperature for a sufficient time to allow complete and uniform penetration of the heat.

SOLIDIFICATION RANGE—The temperature range through which metal freezes or solidifies.

SOLIDUS—The lower line of a fusibility curve, below which the metal is entirely solid.

SONIMS—Solid nonmetallic oxidized inclusions in metal.

SORBITE—A transition form between troostite and pearlite. Sorbite is generally considered as an uncoagulated mixture of troostite and pearlite or an imperfectly developed pearlite.

SPALLING—The cracking and flaking of small particles of metal from the surface.

SPHEROIDIZING—See *annealing*.

SPIEGEL (ALSO SPIEGELEISEN)—A pig iron containing 15 to 30 per cent manganese and 4.5 to 5.5 per cent carbon.

STEAD'S BRITTLINESS—A condition in which the grains of a steel with less than about 0.15 per cent carbon, when heated for a very long time (hours or days) between 930 and 1380 degrees Fahr., are greatly increased in size and the metal becomes brittle.

TAPPING—Removing molten metal from the melting furnace by opening the tap hole and allowing the metal to run out into the ladle.

TEEMING—Pouring molten steel from the ladle into molds.

TEMPERING—See *annealing*.

TEMPER CARBON—A form of graphite in iron base alloys produced by heating below the melting point.

TERNARY ALLOY—An alloy containing three principal elements.

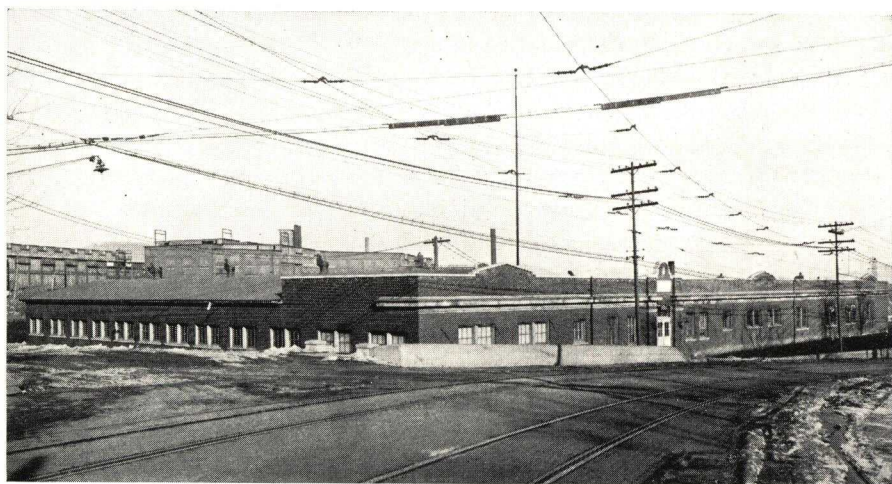
TROOSTITE—A microconstituent of hardened or hardened and tempered steel which etches rapidly and therefore usually appears dark. It consists of a very fine aggregate of ferrite and cementite and is not resolved except at the highest powers of the microscope. Troostite usually occurs in rounded or nodular form.

TWIN CRYSTALS—Crystalline grains or parts of grains, which are symmetrical structurally with respect to a plane between them called the twinning plane. Usually if either part of the twin were revolved a certain amount about an axis perpendicular to the twinning plane, the two parts would possess the same orientation.

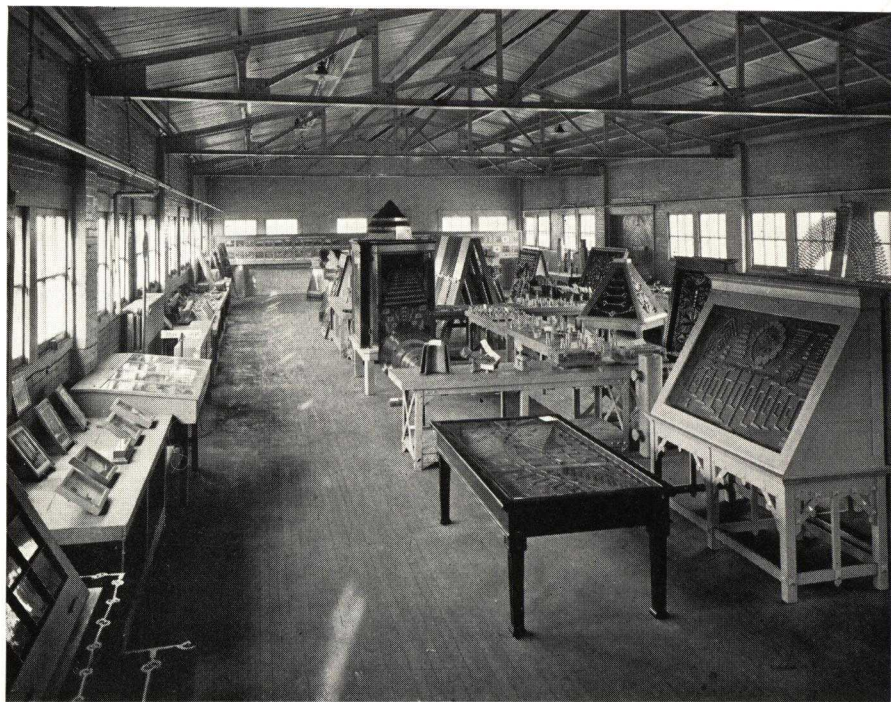
WIDMANSTATTEN STRUCTURE—When the austenite in low-carbon steel transforms to ferrite and pearlite in such a manner as to produce marked precipitation of the ferrite at the crystallographic planes so that the ferrite appears as long continuous plates which occur in definite directions in each grain, the structure is referred to as the Widmanstatten structure. The term is sometimes applied to similar structures in other alloys.

WORK HARDNESS—Hardness developed in metal resulting from mechanical working, particularly cold working.

YOUNG'S MODULUS—See *modulus of elasticity*.



The permanent exhibit building



Part of permanent exhibit building, Bethlehem plant

PART 6

TABLES AND USEFUL INFORMATION

A collection of useful tables and other information, valuable for reference and arranged for general use will be found in the following pages. In part this material has been assembled from a number of sources believed reliable. In part the values have been recalculated or newly calculated to insure a high degree of reliability.

Note: Those interested in the standardization of the value 2.54 cm. for the length of the inch by the American Standards Association on March 13, 1933, and its adoption by more than a dozen countries will understand that the tables, hereinafter, retain the old value of 2.540005080 derived from the American legal standard of 0.3937 inch per cm. This should cause no trouble in five figure computations. Even in six figure computations the last place will not be subject to a change greater than one unit. Only in seven place computations will the last place be subject to a change of more than one unit.

The reason for retaining the old value rests on the important consideration that conversion tables in this book have been recalculated throughout to be fully consistent with the standard values adopted in the International Critical Tables and published in 1926. Furthermore, the Standards authorities have not as yet recalculated and published tables other than those for linear conversions.

Although it is scarcely the province of a handbook of this character to furnish tables for precision work requiring six and seven places of figures, it has been our custom to publish tables accurate to within half of one unit in the last published place. This accuracy could not be retained in the present handbook if we were to revise all tables dependent upon the cm.-inch conversion ratio to the new standard value.

Those having use for the full precision of the tables can easily make the necessary corrections as the number of cm. per inch is reduced almost exactly 2 parts in 1,000,000, or the number of inches per cm. are increased in the same proportion. When derived units contain a power of the conversion ratio, the correction is 4 parts per million for squares, 6 parts per million for cubes or $2n$ parts per million for the n th power.

$\frac{1}{16}$ — $1\frac{31}{32}$ WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square ■	Round ●	Square ▣	Round ●		Square ■	Round ●	Square ▣	Round ●
$\frac{1}{16}$	.013	.010	.0039	.0031	$\frac{13}{16}$	2.245	1.763	.6602	.5185
$\frac{5}{64}$	.021	.016	.0061	.0048	$\frac{53}{64}$	2.332	1.831	.6858	.5386
$\frac{3}{32}$	.030	.023	.0088	.0069	$\frac{27}{32}$	2.420	1.901	.7119	.5591
$\frac{7}{64}$	.041	.032	.0120	.0094	$\frac{55}{64}$	2.511	1.972	.7385	.5800
$\frac{1}{8}$	.053	.042	.0156	.0123	$\frac{7}{8}$	2.603	2.044	.7656	.6013
$\frac{9}{64}$	.067	.053	.0198	.0155	$\frac{57}{64}$	2.697	2.118	.7932	.6230
$\frac{5}{32}$	.083	.065	.0244	.0192	$\frac{29}{32}$	2.792	2.193	.8213	.6450
$\frac{11}{64}$	.100	.079	.0295	.0232	$\frac{59}{64}$	2.889	2.270	.8498	.6675
$\frac{3}{16}$	.120	.094	.0352	.0276	$\frac{15}{16}$	2.988	2.347	.8789	.6903
$\frac{13}{64}$	.140	.110	.0413	.0324	$\frac{61}{64}$	3.089	2.426	.9084	.7135
$\frac{7}{32}$	.163	.128	.0479	.0376	$\frac{31}{32}$	3.191	2.506	.9385	.7371
$\frac{15}{64}$	.187	.147	.0549	.0431	$\frac{63}{64}$	3.294	2.587	.9689	.7610
$\frac{1}{4}$	.212	.167	.0625	.0491	1	3.400	2.670	1.0000	.7854
$\frac{17}{64}$	.240	.188	.0706	.0554	$\frac{1}{32}$	3.616	2.840	1.0635	.8353
$\frac{9}{32}$	.269	.211	.0791	.0621	$\frac{1}{16}$	3.838	3.014	1.1289	.8866
$\frac{19}{64}$	.300	.235	.0881	.0692	$\frac{3}{32}$	4.067	3.194	1.1963	.9396
$\frac{5}{16}$	.332	.261	.0977	.0767	$\frac{1}{8}$	4.303	3.379	1.2656	.9940
$\frac{21}{64}$	.366	.288	.1077	.0846	$\frac{5}{32}$	4.545	3.570	1.3369	1.0500
$\frac{11}{32}$	.402	.316	.1182	.0928	$\frac{3}{16}$	4.795	3.766	1.4102	1.1075
$\frac{23}{64}$	.439	.345	.1292	.1014	$\frac{7}{32}$	5.050	3.966	1.4853	1.1666
$\frac{3}{8}$	.478	.376	.1406	.1104	$\frac{1}{4}$	5.312	4.173	1.5625	1.2272
$\frac{25}{64}$	.519	.407	.1526	.1198	$\frac{9}{32}$	5.581	4.384	1.6416	1.2893
$\frac{13}{32}$	.561	.441	.1650	.1296	$\frac{5}{16}$	5.857	4.600	1.7227	1.3530
$\frac{27}{64}$	.605	.475	.1780	.1398	$\frac{11}{32}$	6.139	4.822	1.8056	1.4182
$\frac{7}{16}$	.651	.511	.1914	.1503	$\frac{3}{8}$	6.428	5.049	1.8906	1.4849
$\frac{29}{64}$	.698	.548	.2053	.1613	$\frac{13}{32}$	6.724	5.281	1.9775	1.5532
$\frac{15}{32}$	.747	.587	.2197	.1726	$\frac{7}{16}$	7.026	5.518	2.0664	1.6230
$\frac{31}{64}$	.798	.627	.2346	.1843	$\frac{15}{32}$	7.334	5.761	2.1572	1.6943
$\frac{1}{2}$	.850	.668	.2500	.1963	$\frac{1}{2}$	7.650	6.008	2.2500	1.7671
$\frac{33}{64}$	.904	.710	.2659	.2088	$\frac{17}{32}$	7.972	6.261	2.3447	1.8415
$\frac{17}{32}$	.960	.754	.2822	.2217	$\frac{9}{16}$	8.301	6.520	2.4414	1.9175
$\frac{35}{64}$	1.017	.799	.2991	.2349	$\frac{19}{32}$	8.636	6.783	2.5400	1.9949
$\frac{9}{16}$	1.076	.845	.3164	.2485	$\frac{5}{8}$	8.978	7.051	2.6406	2.0739
$\frac{37}{64}$	1.136	.893	.3342	.2625	$\frac{21}{32}$	9.327	7.325	2.7431	2.1545
$\frac{19}{32}$	1.199	.941	.3525	.2769	$\frac{11}{16}$	9.682	7.604	2.8477	2.2365
$\frac{39}{64}$	1.263	.992	.3713	.2916	$\frac{23}{32}$	10.044	7.889	2.9541	2.3202
$\frac{5}{8}$	1.328	1.043	.3906	.3068	$\frac{3}{4}$	10.413	8.178	3.0625	2.4053
$\frac{41}{64}$	1.395	1.096	.4104	.3223	$\frac{25}{32}$	10.788	8.473	3.1728	2.4920
$\frac{21}{32}$	1.464	1.150	.4307	.3382	$\frac{13}{16}$	11.170	8.773	3.2852	2.5802
$\frac{43}{64}$	1.535	1.205	.4514	.3545	$\frac{27}{32}$	11.558	9.078	3.3994	2.6699
$\frac{11}{16}$	1.607	1.262	.4727	.3712	$\frac{7}{8}$	11.953	9.388	3.5156	2.7612
$\frac{45}{64}$	1.681	1.320	.4944	.3883	$\frac{29}{32}$	12.355	9.704	3.6337	2.8540
$\frac{23}{32}$	1.756	1.379	.5166	.4057	$\frac{15}{16}$	12.763	10.024	3.7539	2.9483
$\frac{47}{64}$	1.834	1.440	.5393	.4236	$\frac{31}{32}$	13.178	10.350	3.8760	3.0442
$\frac{3}{4}$	1.913	1.502	.5625	.4418					
$\frac{49}{64}$	1.993	1.565	.5862	.4604					
$\frac{25}{32}$	2.075	1.630	.6103	.4794					
$\frac{51}{64}$	2.159	1.696	.6350	.4987					

2—7¹⁵/₁₆WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square ■	Round ●	Square ▨	Round ●		Square ■	Round ●	Square ▨	Round ●
2	13.600	10.681	4.0000	3.1416	5	85.000	66.759	25.000	19.635
$\frac{1}{16}$	14.463	11.359	4.2539	3.3410	$\frac{1}{16}$	87.138	68.438	25.629	20.129
$\frac{1}{8}$	15.353	12.058	4.5156	3.5466	$\frac{1}{8}$	89.303	70.139	26.266	20.629
$\frac{3}{16}$	16.270	12.778	4.7852	3.7583	$\frac{3}{16}$	91.495	71.860	26.910	21.135
$\frac{1}{4}$	17.213	13.519	5.0625	3.9761	$\frac{1}{4}$	93.713	73.602	27.563	21.648
$\frac{5}{16}$	18.182	14.280	5.3477	4.2000	$\frac{5}{16}$	95.957	75.364	28.223	22.166
$\frac{3}{8}$	19.178	15.062	5.6406	4.4301	$\frac{3}{8}$	98.228	77.148	28.891	22.691
$\frac{7}{16}$	20.201	15.866	5.9414	4.6664	$\frac{7}{16}$	100.53	78.953	29.566	23.221
$\frac{1}{2}$	21.250	16.690	6.2500	4.9087	$\frac{1}{2}$	102.85	80.778	30.250	23.758
$\frac{9}{16}$	22.326	17.535	6.5664	5.1572	$\frac{9}{16}$	105.20	82.624	30.941	24.301
$\frac{5}{8}$	23.428	18.400	6.8906	5.4119	$\frac{5}{8}$	107.58	84.492	31.641	24.850
$\frac{11}{16}$	24.557	19.287	7.2227	5.6727	$\frac{11}{16}$	109.98	86.380	32.348	25.406
$\frac{3}{4}$	25.713	20.195	7.5625	5.9396	$\frac{3}{4}$	112.41	88.289	33.063	25.967
$\frac{13}{16}$	26.895	21.123	7.9102	6.2126	$\frac{13}{16}$	114.87	90.218	33.785	26.535
$\frac{7}{8}$	28.103	22.072	8.2656	6.4918	$\frac{7}{8}$	117.35	92.169	34.516	27.109
$\frac{15}{16}$	29.338	23.042	8.6289	6.7771	$\frac{15}{16}$	119.86	94.140	35.254	27.688
3	30.600	24.033	9.0000	7.0686	6	122.40	96.133	36.000	28.274
$\frac{1}{16}$	31.888	25.045	9.3789	7.3662	$\frac{1}{16}$	124.96	98.146	36.754	28.866
$\frac{1}{8}$	33.203	26.078	9.7656	7.6699	$\frac{1}{8}$	127.55	100.18	37.516	29.465
$\frac{3}{16}$	34.545	27.131	10.160	7.9798	$\frac{3}{16}$	130.17	102.23	38.285	30.069
$\frac{1}{4}$	35.913	28.206	10.563	8.2958	$\frac{1}{4}$	132.81	104.31	39.063	30.680
$\frac{5}{16}$	37.307	29.301	10.973	8.6179	$\frac{5}{16}$	135.48	106.41	39.848	31.296
$\frac{3}{8}$	38.728	30.417	11.391	8.9462	$\frac{3}{8}$	138.18	108.52	40.641	31.919
$\frac{7}{16}$	40.176	31.554	11.816	9.2806	$\frac{7}{16}$	140.90	110.66	41.441	32.548
$\frac{1}{2}$	41.650	32.712	12.250	9.6211	$\frac{1}{2}$	143.65	112.82	42.250	33.183
$\frac{9}{16}$	43.151	33.891	12.691	9.9678	$\frac{9}{16}$	146.43	115.00	43.066	33.824
$\frac{5}{8}$	44.678	35.090	13.141	10.321	$\frac{5}{8}$	149.23	117.20	43.891	34.472
$\frac{11}{16}$	46.232	36.311	13.598	10.680	$\frac{11}{16}$	152.06	119.43	44.723	35.125
$\frac{3}{4}$	47.813	37.552	14.063	11.045	$\frac{3}{4}$	154.91	121.67	45.563	35.785
$\frac{13}{16}$	49.420	38.814	14.535	11.416	$\frac{13}{16}$	157.79	123.93	46.410	36.450
$\frac{7}{8}$	51.053	40.097	15.016	11.793	$\frac{7}{8}$	160.70	126.22	47.266	37.122
$\frac{15}{16}$	52.713	41.401	15.504	12.177	$\frac{15}{16}$	163.64	128.52	48.129	37.800
4	54.400	42.726	16.000	12.566	7	166.60	130.85	49.000	38.485
$\frac{1}{16}$	56.113	44.071	16.504	12.962	$\frac{1}{16}$	169.59	133.19	49.879	39.175
$\frac{1}{8}$	57.853	45.438	17.016	13.364	$\frac{1}{8}$	172.60	135.56	50.766	39.871
$\frac{3}{16}$	59.620	46.825	17.535	13.772	$\frac{3}{16}$	175.64	137.95	51.660	40.574
$\frac{1}{4}$	61.413	48.233	18.063	14.186	$\frac{1}{4}$	178.71	140.36	52.563	41.282
$\frac{5}{16}$	63.232	49.662	18.598	14.607	$\frac{5}{16}$	181.81	142.79	53.473	41.997
$\frac{3}{8}$	65.078	51.112	19.141	15.033	$\frac{3}{8}$	184.93	145.24	54.391	42.718
$\frac{7}{16}$	66.951	52.583	19.691	15.466	$\frac{7}{16}$	188.08	147.71	55.316	43.445
$\frac{1}{2}$	68.850	54.075	20.250	15.904	$\frac{1}{2}$	191.25	150.21	56.250	44.179
$\frac{9}{16}$	70.776	55.587	20.816	16.349	$\frac{9}{16}$	194.45	152.72	57.191	44.918
$\frac{5}{8}$	72.728	57.121	21.391	16.800	$\frac{5}{8}$	197.68	155.26	58.141	45.664
$\frac{11}{16}$	74.707	58.675	21.973	17.257	$\frac{11}{16}$	200.93	157.81	59.098	46.415
$\frac{3}{4}$	76.713	60.250	22.563	17.721	$\frac{3}{4}$	204.21	160.39	60.063	47.173
$\frac{13}{16}$	78.745	61.846	23.160	18.190	$\frac{13}{16}$	207.52	162.99	61.035	47.937
$\frac{7}{8}$	80.803	63.463	23.766	18.665	$\frac{7}{8}$	210.85	165.60	62.016	48.707
$\frac{15}{16}$	82.888	65.100	24.379	19.147	$\frac{15}{16}$	214.21	168.24	63.004	49.483

8 — 15 $\frac{7}{8}$ WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square ■	Round ●	Square ▣	Round ●		Square ■	Round ●	Square ▣	Round ●
8	217.60	170.90	64.000	50.266	11	411.40	323.11	121.00	95.033
$\frac{1}{16}$	221.01	173.58	65.004	51.054	$\frac{1}{16}$	416.09	326.79	122.38	96.116
$\frac{1}{8}$	224.45	176.29	66.016	51.849	$\frac{1}{8}$	420.80	330.50	123.77	97.206
$\frac{3}{16}$	227.92	179.01	67.035	52.649	$\frac{3}{16}$	425.54	334.22	125.16	98.301
$\frac{1}{4}$	231.41	181.75	68.063	53.456	$\frac{1}{4}$	430.31	337.97	126.56	99.402
$\frac{5}{16}$	234.93	184.52	69.098	54.269	$\frac{5}{16}$	435.11	341.73	127.97	100.51
$\frac{3}{8}$	238.48	187.30	70.141	55.088	$\frac{3}{8}$	439.93	345.52	129.39	101.62
$\frac{7}{16}$	242.05	190.11	71.191	55.914	$\frac{7}{16}$	444.78	349.33	130.82	102.74
$\frac{1}{2}$	245.65	192.93	72.250	56.745	$\frac{1}{2}$	449.65	353.15	132.25	103.87
$\frac{9}{16}$	249.28	195.78	73.316	57.583	$\frac{9}{16}$	454.55	357.00	133.69	105.00
$\frac{5}{8}$	252.93	198.65	74.391	58.426	$\frac{5}{8}$	459.48	360.87	135.14	106.14
$\frac{11}{16}$	256.61	201.54	75.473	59.276	$\frac{11}{16}$	464.43	364.76	136.60	107.28
$\frac{3}{4}$	260.31	204.45	76.563	60.132	$\frac{3}{4}$	469.41	368.68	138.06	108.43
$\frac{13}{16}$	264.04	207.38	77.660	60.994	$\frac{13}{16}$	474.42	372.61	139.54	109.59
$\frac{7}{8}$	267.80	210.33	78.766	61.863	$\frac{7}{8}$	479.45	376.56	141.02	110.75
$\frac{15}{16}$	271.59	213.30	79.879	62.737	$\frac{15}{16}$	484.51	380.54	142.50	111.92
9	275.40	216.30	81.000	63.617	12	489.60	384.53	144.00	113.10
$\frac{1}{16}$	279.24	219.31	82.129	64.504	$\frac{1}{16}$	499.85	392.58	147.02	115.47
$\frac{1}{8}$	283.10	222.35	83.266	65.397	$\frac{1}{8}$	510.21	400.72	150.06	117.86
$\frac{3}{16}$	286.99	225.40	84.410	66.296	$\frac{3}{16}$	520.68	408.94	153.14	120.28
$\frac{1}{4}$	290.91	228.48	85.563	67.201	$\frac{1}{4}$	531.25	417.24	156.25	122.72
$\frac{5}{16}$	294.86	231.58	86.723	68.112	$\frac{5}{16}$	541.93	425.63	159.39	125.19
$\frac{3}{8}$	298.83	234.70	87.891	69.029	$\frac{3}{8}$	552.71	434.10	162.56	127.68
$\frac{7}{16}$	302.83	237.84	89.066	69.953	$\frac{7}{16}$	563.60	442.65	165.77	130.19
$\frac{1}{2}$	306.85	241.00	90.250	70.882	13	574.60	451.29	169.00	132.73
$\frac{9}{16}$	310.90	244.18	91.441	71.818	$\frac{1}{16}$	585.70	460.01	172.27	135.30
$\frac{5}{8}$	314.98	247.38	92.641	72.760	$\frac{1}{8}$	596.91	468.82	175.56	137.89
$\frac{11}{16}$	319.08	250.61	93.848	73.708	$\frac{3}{16}$	608.23	477.70	178.89	140.50
$\frac{3}{4}$	323.21	253.85	95.063	74.662	$\frac{1}{4}$	619.65	486.67	182.25	143.14
$\frac{13}{16}$	327.37	257.12	96.285	75.622	$\frac{5}{16}$	631.18	495.73	185.64	145.80
$\frac{7}{8}$	331.55	260.40	97.516	76.589	$\frac{3}{8}$	642.81	504.86	189.06	148.49
$\frac{15}{16}$	335.76	263.71	98.754	77.561	$\frac{7}{8}$	654.55	514.09	192.52	151.20
10	340.00	267.04	100.00	78.540	14	666.40	523.39	196.00	153.94
$\frac{1}{16}$	344.26	270.38	101.25	79.525	$\frac{1}{16}$	678.35	532.78	199.52	156.70
$\frac{1}{8}$	348.55	273.75	102.52	80.516	$\frac{1}{8}$	690.41	542.25	203.06	159.49
$\frac{3}{16}$	352.87	277.14	103.79	81.513	$\frac{3}{16}$	702.58	551.80	206.64	162.30
$\frac{1}{4}$	357.21	280.55	105.06	82.516	$\frac{1}{4}$	714.85	561.44	210.25	165.13
$\frac{5}{16}$	361.58	283.99	106.35	83.525	$\frac{5}{16}$	727.23	571.16	213.89	167.99
$\frac{3}{8}$	365.98	287.44	107.64	84.541	$\frac{3}{8}$	739.71	580.97	217.56	170.87
$\frac{7}{16}$	370.40	290.91	108.94	85.563	$\frac{7}{16}$	752.30	590.86	221.27	173.78
$\frac{1}{2}$	374.85	294.41	110.25	86.590	15	765.00	600.83	225.00	176.72
$\frac{9}{16}$	379.33	297.92	111.57	87.624	$\frac{1}{16}$	777.80	610.89	228.77	179.67
$\frac{5}{8}$	383.83	301.46	112.89	88.664	$\frac{1}{8}$	790.71	621.03	232.56	182.65
$\frac{11}{16}$	388.36	305.01	114.22	89.710	$\frac{3}{16}$	803.73	631.25	236.39	185.66
$\frac{3}{4}$	392.91	308.59	115.56	90.763	$\frac{1}{4}$	816.85	641.55	240.25	188.69
$\frac{13}{16}$	397.49	312.19	116.91	91.821	$\frac{5}{16}$	830.08	651.94	244.14	191.75
$\frac{7}{8}$	402.10	315.81	118.27	92.886	$\frac{3}{8}$	843.41	662.42	248.06	194.83
$\frac{15}{16}$	406.74	319.45	119.63	93.957	$\frac{7}{8}$	856.85	672.97	252.02	197.93

16—27⁷/₈

WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square ■	Round ●	Square ▣	Round ●		Square ■	Round ●	Square ▣	Round ●
16	870.40	683.61	256.00	201.06	22	1645.6	1292.5	484.00	380.13
¹ / ₈	884.05	694.34	260.02	204.22	¹ / ₈	1664.4	1307.2	489.52	384.47
¹ / ₄	897.81	705.14	264.06	207.39	¹ / ₄	1683.2	1322.0	495.06	388.82
³ / ₈	911.68	716.03	268.14	210.60	³ / ₈	1702.2	1336.9	500.64	393.20
¹ / ₂	925.65	727.01	272.25	213.83	¹ / ₂	1721.3	1351.9	506.25	397.61
⁵ / ₈	939.73	738.06	276.39	217.08	⁵ / ₈	1740.4	1366.9	511.89	402.04
³ / ₄	953.91	749.20	280.56	220.35	³ / ₄	1759.7	1382.1	517.56	406.49
⁷ / ₈	968.20	760.43	284.77	223.65	⁷ / ₈	1779.1	1397.3	523.27	410.97
17	982.60	771.73	289.00	226.98	23	1798.6	1412.6	529.00	415.48
¹ / ₈	997.10	783.12	293.27	230.33	¹ / ₈	1818.2	1428.0	534.77	420.00
¹ / ₄	1011.71	794.60	297.56	233.71	¹ / ₄	1837.9	1443.5	540.56	424.56
³ / ₈	1026.43	806.16	301.89	237.10	³ / ₈	1857.7	1459.1	546.39	429.14
¹ / ₂	1041.25	817.80	306.25	240.53	¹ / ₂	1877.7	1474.7	552.25	433.74
⁵ / ₈	1056.18	829.52	310.64	243.98	⁵ / ₈	1897.7	1490.4	558.14	438.36
³ / ₄	1071.21	841.33	315.06	247.45	³ / ₄	1917.8	1506.2	564.06	443.01
⁷ / ₈	1086.35	853.22	319.52	250.95	⁷ / ₈	1938.1	1522.1	570.02	447.69
18	1101.60	865.20	324.00	254.47	24	1958.4	1538.1	576.00	452.39
¹ / ₈	1117.0	877.25	328.52	258.02	¹ / ₈	1978.9	1554.2	582.02	457.12
¹ / ₄	1132.4	889.40	333.06	261.59	¹ / ₄	1999.4	1570.3	588.06	461.86
³ / ₈	1148.0	901.62	337.64	265.18	³ / ₈	2020.1	1586.6	594.14	466.64
¹ / ₂	1163.7	913.93	342.25	268.80	¹ / ₂	2040.9	1602.9	600.25	471.44
⁵ / ₈	1179.4	926.32	346.89	272.45	⁵ / ₈	2061.7	1619.3	606.39	476.26
³ / ₄	1195.3	938.80	351.56	276.12	³ / ₄	2082.7	1635.8	612.56	481.11
⁷ / ₈	1211.3	951.36	356.27	279.81	⁷ / ₈	2103.8	1652.3	618.77	485.98
19	1227.4	964.00	361.00	283.53	25	2125.0	1669.0	625.00	490.88
¹ / ₈	1243.6	976.73	365.77	287.27	¹ / ₈	2146.3	1685.7	631.27	495.80
¹ / ₄	1259.9	989.54	370.56	291.04	¹ / ₄	2167.7	1702.5	637.56	500.74
³ / ₈	1276.3	1002.43	375.39	294.83	³ / ₈	2189.2	1719.4	643.89	505.71
¹ / ₂	1292.9	1015.40	380.25	298.65	¹ / ₂	2210.9	1736.4	650.25	510.71
⁵ / ₈	1309.5	1028.46	385.14	302.49	⁵ / ₈	2232.6	1753.5	656.64	515.73
³ / ₄	1326.2	1041.6	390.06	306.35	³ / ₄	2254.4	1770.6	663.06	520.77
⁷ / ₈	1343.1	1054.8	395.02	310.24	⁷ / ₈	2276.4	1787.8	669.52	525.84
20	1360.0	1068.1	400.00	314.16	26	2298.4	1805.2	676.00	530.93
¹ / ₈	1377.1	1081.5	405.02	318.10	¹ / ₈	2320.6	1822.6	682.52	536.05
¹ / ₄	1394.2	1095.0	410.06	322.06	¹ / ₄	2342.8	1840.0	689.06	541.19
³ / ₈	1411.5	1108.6	415.14	326.05	³ / ₈	2365.2	1857.6	695.64	546.36
¹ / ₂	1428.9	1122.2	420.25	330.06	¹ / ₂	2387.7	1875.3	702.25	551.55
⁵ / ₈	1446.3	1135.9	425.39	334.10	⁵ / ₈	2410.2	1893.0	708.89	556.76
³ / ₄	1463.9	1149.8	430.56	338.16	³ / ₄	2432.9	1910.8	715.56	562.00
⁷ / ₈	1481.6	1163.7	435.77	342.25	⁷ / ₈	2455.7	1928.7	722.27	567.27
21	1499.4	1177.6	441.00	346.36	27	2478.6	1946.7	729.00	572.56
¹ / ₈	1517.3	1191.7	446.27	350.50	¹ / ₈	2501.6	1964.8	735.77	577.87
¹ / ₄	1535.3	1205.8	451.56	354.66	¹ / ₄	2524.7	1982.9	742.56	583.21
³ / ₈	1553.4	1220.1	456.89	358.84	³ / ₈	2547.9	2001.1	749.39	588.57
¹ / ₂	1571.7	1234.4	462.25	363.05	¹ / ₂	2571.3	2019.5	756.25	593.96
⁵ / ₈	1590.0	1248.8	467.64	367.28	⁵ / ₈	2594.7	2037.9	763.14	599.37
³ / ₄	1608.4	1263.2	473.06	371.54	³ / ₄	2618.2	2056.3	770.06	604.81
⁷ / ₈	1627.0	1277.8	478.52	375.83	⁷ / ₈	2641.9	2074.9	777.02	610.27

28—43 $\frac{3}{4}$ WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. in.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. in.	
	Square 	Round 	Square 	Round 		Square 	Round 	Square 	Round 
28	2665.6	2093.6	784.00	615.75	34	3930.4	3086.9	1156.00	907.92
$\frac{1}{8}$	2689.5	2112.3	791.02	621.26	$\frac{1}{8}$	3959.4	3109.7	1164.52	914.61
$\frac{1}{4}$	2713.4	2131.1	798.06	626.80	$\frac{1}{4}$	3988.4	3132.5	1173.06	921.32
$\frac{3}{8}$	2737.5	2150.0	805.14	632.36	$\frac{3}{8}$	4017.6	3155.4	1181.64	928.06
$\frac{1}{2}$	2761.7	2169.0	812.25	637.94	$\frac{1}{2}$	4046.9	3178.4	1190.25	934.82
$\frac{5}{8}$	2785.9	2188.1	819.39	643.55	$\frac{5}{8}$	4076.2	3201.5	1198.89	941.61
$\frac{3}{4}$	2810.3	2207.2	826.56	649.18	$\frac{3}{4}$	4105.7	3224.6	1207.56	948.42
$\frac{7}{8}$	2834.8	2226.5	833.77	654.84	$\frac{7}{8}$	4135.3	3247.9	1216.27	955.26
29	2859.4	2245.8	841.00	660.52	35	4165.0	3271.2	1225.00	962.12
$\frac{1}{8}$	2884.1	2265.2	848.27	666.23	$\frac{1}{8}$	4194.8	3294.6	1233.77	969.00
$\frac{1}{4}$	2908.9	2284.7	855.56	671.96	$\frac{1}{4}$	4224.7	3318.1	1242.56	975.91
$\frac{3}{8}$	2933.8	2304.2	862.89	677.71	$\frac{3}{8}$	4254.7	3341.7	1251.39	982.84
$\frac{1}{2}$	2958.9	2323.9	870.25	683.49	$\frac{1}{2}$	4284.9	3365.3	1260.25	989.80
$\frac{5}{8}$	2984.0	2343.6	877.64	689.30	$\frac{5}{8}$	4315.1	3389.1	1269.14	996.78
$\frac{3}{4}$	3009.2	2363.4	885.06	695.13	$\frac{3}{4}$	4345.4	3412.9	1278.06	1003.79
$\frac{7}{8}$	3034.6	2383.3	892.52	700.98	$\frac{7}{8}$	4375.9	3436.8	1287.02	1010.82
30	3060.0	2403.3	900.00	706.86	36	4406.4	3460.8	1296.00	1017.88
$\frac{1}{8}$	3085.6	2423.4	907.52	712.76	$\frac{1}{8}$	4467.8	3509.0	1314.1	1032.1
$\frac{1}{4}$	3111.2	2443.5	915.06	718.69	$\frac{1}{4}$	4529.7	3557.6	1332.3	1046.4
$\frac{3}{8}$	3137.0	2463.8	922.64	724.64	$\frac{3}{8}$	4591.9	3606.5	1350.6	1060.7
$\frac{1}{2}$	3162.9	2484.1	930.25	730.62	37	4654.6	3655.7	1369.0	1075.2
$\frac{5}{8}$	3188.8	2504.5	937.89	736.62	$\frac{1}{8}$	4717.7	3705.3	1387.6	1089.8
$\frac{3}{4}$	3214.9	2525.0	945.56	742.64	$\frac{1}{4}$	4781.3	3755.2	1406.3	1104.5
$\frac{7}{8}$	3241.1	2545.6	953.27	748.69	$\frac{3}{4}$	4845.2	3805.4	1425.1	1119.2
31	3267.4	2566.2	961.00	754.77	38	4909.6	3856.0	1444.0	1134.1
$\frac{1}{8}$	3293.8	2587.0	968.77	760.87	$\frac{1}{8}$	4974.4	3906.9	1463.1	1149.1
$\frac{1}{4}$	3320.3	2607.8	976.56	766.99	$\frac{1}{4}$	5039.7	3958.1	1482.3	1164.2
$\frac{3}{8}$	3346.9	2628.7	984.39	773.14	$\frac{3}{8}$	5105.3	4009.7	1501.6	1179.3
$\frac{1}{2}$	3373.7	2649.7	992.25	779.31	39	5171.4	4061.6	1521.0	1194.6
$\frac{5}{8}$	3400.5	2670.7	1000.14	785.51	$\frac{1}{8}$	5237.9	4113.9	1540.6	1210.0
$\frac{3}{4}$	3427.4	2691.9	1008.06	791.73	$\frac{1}{4}$	5304.9	4166.4	1560.3	1225.4
$\frac{7}{8}$	3454.5	2713.1	1016.02	797.98	$\frac{3}{4}$	5372.2	4219.3	1580.1	1241.0
32	3481.6	2734.4	1024.00	804.25	40	5440.0	4272.6	1600.0	1256.6
$\frac{1}{8}$	3508.9	2755.9	1032.02	810.55	$\frac{1}{8}$	5508.2	4326.2	1620.1	1272.4
$\frac{1}{4}$	3536.2	2777.3	1040.06	816.87	$\frac{1}{4}$	5576.9	4380.1	1640.3	1288.3
$\frac{3}{8}$	3563.7	2798.9	1048.14	823.21	$\frac{3}{8}$	5645.9	4434.3	1660.6	1304.2
$\frac{1}{2}$	3591.3	2820.6	1056.25	829.58	41	5715.4	4488.9	1681.0	1320.3
$\frac{5}{8}$	3618.9	2842.3	1064.39	835.97	$\frac{1}{8}$	5785.3	4543.8	1701.6	1336.4
$\frac{3}{4}$	3646.7	2864.1	1072.56	842.39	$\frac{1}{4}$	5855.7	4599.0	1722.3	1352.7
$\frac{7}{8}$	3674.6	2886.0	1080.77	848.83	$\frac{3}{4}$	5926.4	4654.6	1743.1	1369.0
33	3702.6	2908.0	1089.00	855.30	42	5997.6	4710.5	1764.0	1385.5
$\frac{1}{8}$	3730.7	2930.1	1097.27	861.79	$\frac{1}{8}$	6069.2	4766.8	1785.1	1402.0
$\frac{1}{4}$	3758.9	2952.2	1105.56	868.31	$\frac{1}{4}$	6141.3	4823.3	1806.3	1418.6
$\frac{3}{8}$	3787.2	2974.5	1113.89	874.85	$\frac{3}{8}$	6213.7	4880.2	1827.6	1435.4
$\frac{1}{2}$	3815.7	2996.8	1122.25	881.42	43	6286.6	4937.5	1849.0	1452.2
$\frac{5}{8}$	3844.2	3019.2	1130.64	888.01	$\frac{1}{8}$	6359.9	4995.1	1870.6	1469.1
$\frac{3}{4}$	3872.8	3041.7	1139.06	894.62	$\frac{1}{4}$	6433.7	5053.0	1892.3	1486.2
$\frac{7}{8}$	3901.6	3064.3	1147.52	901.26	$\frac{3}{4}$	6507.8	5111.2	1914.1	1503.3

44—67³/₄WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square ■	Round ●	Square ▣	Round ●		Square ■	Round ●	Square ▣	Round ●
44	6582.4	5169.8	1936.0	1520.5	56	10662.4	8374.2	3136.0	2463.0
1/4	6657.4	5228.7	1958.1	1537.9	1/4	10757.8	8449.2	3164.1	2485.1
1/2	6732.9	5288.0	1980.3	1555.3	1/2	10853.7	8524.5	3192.3	2507.2
3/4	6808.7	5347.6	2002.6	1572.8	3/4	10949.9	8600.1	3220.6	2529.4
45	6885.0	5407.5	2025.0	1590.4	57	11046.6	8676.0	3249.0	2551.8
1/4	6961.7	5467.7	2047.6	1608.2	1/4	11143.7	8752.3	3277.6	2574.2
1/2	7038.9	5528.3	2070.3	1626.0	1/2	11241.3	8828.9	3306.3	2596.7
3/4	7116.4	5589.2	2093.1	1643.9	3/4	11339.2	8905.8	3335.1	2619.4
46	7194.4	5650.5	2116.0	1661.9	58	11437.6	8983.1	3364.0	2642.1
1/4	7272.8	5712.1	2139.1	1680.0	1/4	11536.4	9060.7	3393.1	2664.9
1/2	7351.7	5774.0	2162.3	1698.2	1/2	11635.7	9138.6	3422.3	2687.8
3/4	7430.9	5836.2	2185.6	1716.5	3/4	11735.3	9216.9	3451.6	2710.9
47	7510.6	5898.8	2209.0	1734.9	59	11835.4	9295.5	3481.0	2734.0
1/4	7590.7	5961.7	2232.6	1753.5	1/4	11935.9	9374.5	3510.6	2757.2
1/2	7671.3	6025.0	2256.3	1772.1	1/2	12036.9	9453.7	3540.3	2780.5
3/4	7752.2	6088.6	2280.1	1790.8	3/4	12138.2	9533.4	3570.1	2803.9
48	7833.6	6152.5	2304.0	1809.6	60	12240.0	9613.3	3600.0	2827.4
1/4	7915.4	6216.8	2328.1	1828.5	1/4	12342	9693.6	3630.1	2851.1
1/2	7997.7	6281.4	2352.3	1847.5	1/2	12445	9774.2	3660.3	2874.8
3/4	8080.3	6346.3	2376.6	1866.6	3/4	12548	9855.1	3690.6	2898.6
49	8163.4	6411.5	2401.0	1885.7	61	12651	9936.4	3721.0	2922.5
1/4	8246.9	6477.1	2425.6	1905.0	1/4	12755	10018.0	3751.6	2946.5
1/2	8330.9	6543.0	2450.3	1924.4	1/2	12860	10100.0	3782.3	2970.6
3/4	8415.2	6609.3	2475.1	1943.9	3/4	12964	10182.2	3813.1	2994.8
50	8500.0	6675.9	2500.0	1963.5	62	13070	10264.9	3844.0	3019.1
1/4	8585.2	6742.8	2525.1	1983.2	1/4	13175	10347.8	3875.1	3043.5
1/2	8670.9	6810.1	2550.3	2003.0	1/2	13281	10431.1	3906.3	3068.0
3/4	8756.9	6877.7	2575.6	2022.8	3/4	13388	10514.7	3937.6	3092.6
51	8843.4	6945.6	2601.0	2042.8	63	13495	10598.7	3969.0	3117.3
1/4	8930.3	7013.9	2626.6	2062.9	1/4	13602	10682.9	4000.6	3142.0
1/2	9017.7	7082.5	2652.3	2083.1	1/2	13710	10767.6	4032.3	3166.9
3/4	9105.4	7151.4	2678.1	2103.4	3/4	13818	10852.5	4064.1	3191.9
52	9193.6	7220.7	2704.0	2123.7	64	13926	10937.8	4096.0	3217.0
1/4	9282.2	7290.2	2730.1	2144.2	1/4	14035	11023.4	4128.1	3242.2
1/2	9371.3	7360.2	2756.3	2164.8	1/2	14145	11109.4	4160.3	3267.5
3/4	9460.7	7430.4	2782.6	2185.4	3/4	14255	11195.7	4192.6	3292.8
53	9550.6	7501.0	2809.0	2206.2	65	14365	11282.3	4225.0	3318.3
1/4	9640.9	7572.0	2835.6	2227.1	1/4	14476	11369.2	4257.6	3343.9
1/2	9731.7	7643.2	2862.3	2248.0	1/2	14587	11456.5	4290.3	3369.6
3/4	9822.8	7714.8	2889.1	2269.1	3/4	14698	11544.1	4323.1	3395.3
54	9914.4	7786.8	2916.0	2290.2	66	14810	11632.1	4356.0	3421.2
1/4	10006.4	7859.0	2943.1	2311.5	1/4	14923	11720.4	4389.1	3447.2
1/2	10098.9	7931.6	2970.3	2332.8	1/2	15036	11809.0	4422.3	3473.2
3/4	10191.7	8004.6	2997.6	2354.3	3/4	15149	11898.0	4455.6	3499.4
55	10285.0	8077.8	3025.0	2375.8	67	15263	11987.2	4489.0	3525.7
1/4	10378.7	8151.4	3052.6	2397.5	1/4	15377	12076.9	4522.6	3552.0
1/2	10472.9	8225.4	3080.3	2419.2	1/2	15491	12166.8	4556.3	3578.5
3/4	10567.4	8299.6	3108.1	2441.1	3/4	15606	12257.1	4590.1	3605.0

68—91 $\frac{3}{4}$ WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square ■	Round ●	Square ▨	Round ●		Square ■	Round ●	Square ▨	Round ●
68	15722	12347.7	4624.0	3631.7	80	21760	17090	6400.0	5026.5
$\frac{1}{4}$	15837	12438.7	4658.1	3658.4	$\frac{1}{4}$	21896	17197	6440.1	5058.0
$\frac{1}{2}$	15954	12530.0	4692.3	3685.3	$\frac{1}{2}$	22033	17305	6480.3	5089.6
$\frac{3}{4}$	16070	12621.6	4726.6	3712.2	$\frac{3}{4}$	22170	17412	6520.6	5121.2
69	16187	12713.6	4761.0	3739.3	81	22307	17520	6561.0	5153.0
$\frac{1}{4}$	16305	12805.9	4795.6	3766.4	$\frac{1}{4}$	22445	17629	6601.6	5184.9
$\frac{1}{2}$	16423	12898.5	4830.3	3793.7	$\frac{1}{2}$	22584	17737	6642.3	5216.8
$\frac{3}{4}$	16541	12991.5	4865.1	3821.0	$\frac{3}{4}$	22722	17846	6683.1	5248.9
70	16660	13084.8	4900.0	3848.5	82	22862	17955	6724.0	5281.0
$\frac{1}{4}$	16779	13178.4	4935.1	3876.0	$\frac{1}{4}$	23001	18065	6765.1	5313.3
$\frac{1}{2}$	16899	13272.4	4970.3	3903.6	$\frac{1}{2}$	23141	18175	6806.3	5345.6
$\frac{3}{4}$	17019	13366.7	5005.6	3931.4	$\frac{3}{4}$	23282	18285	6847.6	5378.1
71	17139	13461.3	5041.0	3959.2	83	23423	18396	6889.0	5410.6
$\frac{1}{4}$	17260	13556.2	5076.6	3987.1	$\frac{1}{4}$	23564	18507	6930.6	5443.3
$\frac{1}{2}$	17382	13651.5	5112.3	4015.2	$\frac{1}{2}$	23706	18618	6972.3	5476.0
$\frac{3}{4}$	17503	13747.2	5148.1	4043.3	$\frac{3}{4}$	23848	18730	7014.1	5508.8
72	17626	13843.1	5184.0	4071.5	84	23990	18842	7056.0	5541.8
$\frac{1}{4}$	17748	13939	5220.1	4099.8	$\frac{1}{4}$	24133	18954	7098.1	5574.8
$\frac{1}{2}$	17871	14036	5256.3	4128.2	$\frac{1}{2}$	24277	19067	7140.3	5607.9
$\frac{3}{4}$	17995	14133	5292.6	4156.8	$\frac{3}{4}$	24421	19180	7182.6	5641.2
73	18119	14230	5329.0	4185.4	85	24565	19293	7225.0	5674.5
$\frac{1}{4}$	18243	14328	5365.6	4214.1	$\frac{1}{4}$	24710	19407	7267.6	5707.9
$\frac{1}{2}$	18368	14426	5402.3	4242.9	$\frac{1}{2}$	24855	19521	7310.3	5741.5
$\frac{3}{4}$	18493	14524	5439.1	4271.8	$\frac{3}{4}$	25000	19635	7353.1	5775.1
74	18618	14623	5476.0	4300.8	86	25146	19750	7396.0	5808.8
$\frac{1}{4}$	18744	14722	5513.1	4329.9	$\frac{1}{4}$	25293	19865	7439.1	5842.6
$\frac{1}{2}$	18871	14821	5550.3	4359.2	$\frac{1}{2}$	25440	19980	7482.3	5876.5
$\frac{3}{4}$	18998	14921	5587.6	4388.5	$\frac{3}{4}$	25587	20096	7525.6	5910.6
75	19125	15021	5625.0	4417.9	87	25735	20212	7569.0	5944.7
$\frac{1}{4}$	19253	15121	5662.6	4447.4	$\frac{1}{4}$	25883	20328	7612.6	5978.9
$\frac{1}{2}$	19381	15222	5700.3	4477.0	$\frac{1}{2}$	26031	20445	7656.3	6013.2
$\frac{3}{4}$	19509	15323	5738.1	4506.7	$\frac{3}{4}$	26180	20562	7700.1	6047.6
76	19638	15424	5776.0	4536.5	88	26330	20679	7744.0	6082.1
$\frac{1}{4}$	19768	15526	5814.1	4566.4	$\frac{1}{4}$	26479	20797	7788.1	6116.7
$\frac{1}{2}$	19898	15628	5852.3	4596.3	$\frac{1}{2}$	26630	20915	7832.3	6151.4
$\frac{3}{4}$	20028	15730	5890.6	4626.4	$\frac{3}{4}$	26780	21033	7876.6	6186.2
77	20159	15833	5929.0	4656.6	89	26931	21152	7921.0	6221.1
$\frac{1}{4}$	20290	15936	5967.6	4686.9	$\frac{1}{4}$	27083	21271	7965.6	6256.1
$\frac{1}{2}$	20421	16039	6006.3	4717.3	$\frac{1}{2}$	27235	21390	8010.3	6291.2
$\frac{3}{4}$	20553	16142	6045.1	4747.8	$\frac{3}{4}$	27387	21510	8055.1	6326.4
78	20686	16246	6084.0	4778.4	90	27540	21630	8100.0	6361.7
$\frac{1}{4}$	20818	16351	6123.1	4809.0	$\frac{1}{4}$	27693	21750	8145.1	6397.1
$\frac{1}{2}$	20952	16455	6162.3	4839.8	$\frac{1}{2}$	27847	21871	8190.3	6432.6
$\frac{3}{4}$	21085	16560	6201.6	4870.7	$\frac{3}{4}$	28001	21992	8235.6	6468.2
79	21219	16666	6241.0	4901.7	91	28155	22113	8281.0	6503.9
$\frac{1}{4}$	21354	16771	6280.6	4932.7	$\frac{1}{4}$	28310	22235	8326.6	6539.7
$\frac{1}{2}$	21489	16877	6320.3	4963.9	$\frac{1}{2}$	28466	22357	8372.3	6575.5
$\frac{3}{4}$	21624	16984	6360.1	4995.2	$\frac{3}{4}$	28621	22479	8418.1	6611.5

92—115 $\frac{3}{4}$ WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square 	Round 	Square 	Round 		Square 	Round 	Square 	Round 
92	28778	22602	8464.0	6647.6	104	36774	28883	10816	8494.9
$\frac{1}{4}$	28934	22725	8510.1	6683.8	$\frac{1}{4}$	36951	29022	10868	8535.8
$\frac{1}{2}$	29091	22848	8556.3	6720.1	$\frac{1}{2}$	37129	29161	10920	8576.7
$\frac{3}{4}$	29249	22972	8602.6	6756.4	$\frac{3}{4}$	37307	29301	10973	8617.8
93	29407	23096	8649.0	6792.9	105	37485	29441	11025	8659.0
$\frac{1}{4}$	29565	23220	8695.6	6829.5	$\frac{1}{4}$	37664	29581	11078	8700.3
$\frac{1}{2}$	29724	23345	8742.3	6866.1	$\frac{1}{2}$	37843	29722	11130	8741.7
$\frac{3}{4}$	29883	23470	8789.1	6902.9	$\frac{3}{4}$	38022	29863	11183	8783.2
94	30042	23595	8836.0	6939.8	106	38202	30004	11236	8824.7
$\frac{1}{4}$	30202	23721	8883.1	6976.7	$\frac{1}{4}$	38383	30146	11289	8866.4
$\frac{1}{2}$	30363	23847	8930.3	7013.8	$\frac{1}{2}$	38564	30288	11342	8908.2
$\frac{3}{4}$	30524	23973	8977.6	7051.0	$\frac{3}{4}$	38745	30430	11396	8950.1
95	30685	24100	9025.0	7088.2	107	38927	30573	11449	8992.0
$\frac{1}{4}$	30847	24227	9072.6	7125.6	$\frac{1}{4}$	39109	30716	11503	9034.1
$\frac{1}{2}$	31009	24354	9120.3	7163.0	$\frac{1}{2}$	39291	30859	11556	9076.3
$\frac{3}{4}$	31171	24481	9168.1	7200.6	$\frac{3}{4}$	39474	31003	11610	9118.5
96	31334	24610	9216.0	7238.2	108	39658	31147	11664	9160.9
$\frac{1}{4}$	31498	24738	9264.1	7276.0	$\frac{1}{4}$	39841	31291	11718	9203.3
$\frac{1}{2}$	31662	24867	9312.3	7313.8	$\frac{1}{2}$	40026	31436	11772	9245.9
$\frac{3}{4}$	31826	24996	9360.6	7351.8	$\frac{3}{4}$	40210	31581	11827	9288.6
97	31991	25125	9409.0	7389.8	109	40395	31726	11881	9331.3
$\frac{1}{4}$	32156	25255	9457.6	7428.0	$\frac{1}{4}$	40581	31872	11936	9374.2
$\frac{1}{2}$	32321	25385	9506.3	7466.2	$\frac{1}{2}$	40767	32018	11990	9417.1
$\frac{3}{4}$	32487	25515	9555.1	7504.5	$\frac{3}{4}$	40953	32165	12045	9460.2
98	32654	25646	9604.0	7543.0	110	41140	32311	12100	9503.3
$\frac{1}{4}$	32820	25777	9653.1	7581.5	$\frac{1}{4}$	41327	32458	12155	9546.6
$\frac{1}{2}$	32988	25908	9702.3	7620.1	$\frac{1}{2}$	41515	32606	12210	9589.9
$\frac{3}{4}$	33155	26040	9751.6	7658.9	$\frac{3}{4}$	41703	32753	12266	9633.4
99	33323	26172	9801.0	7697.7	111	41891	32901	12321	9676.9
$\frac{1}{4}$	33492	26304	9850.6	7736.6	$\frac{1}{4}$	42080	33050	12377	9720.5
$\frac{1}{2}$	33661	26437	9900.3	7775.6	$\frac{1}{2}$	42270	33199	12432	9764.3
$\frac{3}{4}$	33830	26570	9950.1	7814.8	$\frac{3}{4}$	42459	33348	12488	9808.1
100	34000	26704	10000	7854.0	112	42650	33497	12544	9852.0
$\frac{1}{4}$	34170	26837	10050	7893.3	$\frac{1}{4}$	42840	33647	12600	9896.1
$\frac{1}{2}$	34341	26971	10100	7932.7	$\frac{1}{2}$	43031	33797	12656	9940.2
$\frac{3}{4}$	34512	27106	10151	7972.2	$\frac{3}{4}$	43223	33947	12713	9984.4
101	34683	27240	10201	8011.8	113	43415	34098	12769	10029
$\frac{1}{4}$	34855	27375	10252	8051.6	$\frac{1}{4}$	43607	34249	12826	10073
$\frac{1}{2}$	35028	27511	10302	8091.4	$\frac{1}{2}$	43800	34400	12882	10118
$\frac{3}{4}$	35200	27646	10353	8131.3	$\frac{3}{4}$	43993	34552	12939	10162
102	35374	27782	10404	8171.3	114	44186	34704	12996	10207
$\frac{1}{4}$	35547	27919	10455	8211.4	$\frac{1}{4}$	44380	34856	13053	10252
$\frac{1}{2}$	35721	28055	10506	8251.6	$\frac{1}{2}$	44575	35009	13110	10297
$\frac{3}{4}$	35896	28192	10558	8291.9	$\frac{3}{4}$	44770	35162	13168	10342
103	36071	28330	10609	8332.3	115	44965	35315	13225	10387
$\frac{1}{4}$	36246	28467	10661	8372.8	$\frac{1}{4}$	45161	35469	13283	10432
$\frac{1}{2}$	36422	28605	10712	8413.4	$\frac{1}{2}$	45357	35623	13340	10477
$\frac{3}{4}$	36598	28744	10764	8454.1	$\frac{3}{4}$	45553	35778	13398	10523

116 — 139 $\frac{3}{4}$ WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square ■	Round ●	Square ■	Round ●		Square ■	Round ●	Square ■	Round ●
116	45750	35932	13456	10568	128	55706	43751	16384	12868
$\frac{1}{4}$	45948	36087	13514	10614	$\frac{1}{4}$	55923	43922	16448	12918
$\frac{1}{2}$	46146	36243	13572	10660	$\frac{1}{2}$	56142	44094	16512	12969
$\frac{3}{4}$	46344	36398	13631	10705	$\frac{3}{4}$	56360	44265	16577	13019
117	46543	36554	13689	10751	129	56579	44437	16641	13070
$\frac{1}{4}$	46742	36711	13748	10797	$\frac{1}{4}$	56799	44610	16706	13121
$\frac{1}{2}$	46941	36868	13806	10843	$\frac{1}{2}$	57019	44783	16770	13171
$\frac{3}{4}$	47141	37025	13865	10890	$\frac{3}{4}$	57239	44956	16835	13222
118	47342	37182	13924	10936	130	57460	45129	16900	13273
$\frac{1}{4}$	47542	37340	13983	10982	$\frac{1}{4}$	57681	45303	16965	13324
$\frac{1}{2}$	47744	37498	14042	11029	$\frac{1}{2}$	57903	45477	17030	13376
$\frac{3}{4}$	47945	37656	14102	11075	$\frac{3}{4}$	58125	45651	17096	13427
119	48147	37815	14161	11122	131	58347	45826	17161	13478
$\frac{1}{4}$	48350	37974	14221	11169	$\frac{1}{4}$	58570	46001	17227	13530
$\frac{1}{2}$	48553	38133	14280	11216	$\frac{1}{2}$	58794	46177	17292	13581
$\frac{3}{4}$	48756	38293	14340	11263	$\frac{3}{4}$	59017	46352	17358	13633
120	48960	38453	14400	11310	132	59242	46528	17424	13685
$\frac{1}{4}$	49164	38614	14460	11357	$\frac{1}{4}$	59466	46705	17490	13737
$\frac{1}{2}$	49369	38774	14520	11404	$\frac{1}{2}$	59691	46882	17556	13789
$\frac{3}{4}$	49574	38935	14581	11452	$\frac{3}{4}$	59917	47059	17623	13841
121	49779	39097	14641	11499	133	60143	47236	17689	13893
$\frac{1}{4}$	49985	39258	14702	11547	$\frac{1}{4}$	60369	47414	17756	13945
$\frac{1}{2}$	50192	39421	14762	11594	$\frac{1}{2}$	60596	47592	17822	13998
$\frac{3}{4}$	50398	39583	14823	11642	$\frac{3}{4}$	60823	47770	17889	14050
122	50606	39746	14884	11690	134	61050	47949	17956	14103
$\frac{1}{4}$	50813	39909	14945	11738	$\frac{1}{4}$	61278	48128	18023	14155
$\frac{1}{2}$	51021	40072	15006	11786	$\frac{1}{2}$	61507	48307	18090	14208
$\frac{3}{4}$	51230	40236	15068	11834	$\frac{3}{4}$	61736	48487	18158	14261
123	51439	40400	15129	11882	135	61965	48667	18225	14314
$\frac{1}{4}$	51648	40564	15191	11931	$\frac{1}{4}$	62195	48848	18293	14367
$\frac{1}{2}$	51858	40729	15252	11979	$\frac{1}{2}$	62425	49028	18360	14420
$\frac{3}{4}$	52068	40894	15314	12028	$\frac{3}{4}$	62655	49210	18428	14473
124	52278	41059	15376	12076	136	62886	49391	18496	14527
$\frac{1}{4}$	52489	41225	15438	12125	$\frac{1}{4}$	63118	49573	18564	14580
$\frac{1}{2}$	52701	41391	15500	12174	$\frac{1}{2}$	63350	49755	18632	14634
$\frac{3}{4}$	52913	41558	15563	12223	$\frac{3}{4}$	63582	49937	18701	14687
125	53125	41724	15625	12272	137	63815	50120	18769	14741
$\frac{1}{4}$	53337	41891	15688	12321	$\frac{1}{4}$	64048	50303	18838	14795
$\frac{1}{2}$	53551	42059	15750	12370	$\frac{1}{2}$	64281	50486	18906	14849
$\frac{3}{4}$	53764	42227	15813	12420	$\frac{3}{4}$	64515	50670	18975	14903
126	53978	42395	15876	12469	138	64750	50854	19044	14957
$\frac{1}{4}$	54193	42563	15939	12519	$\frac{1}{4}$	64984	51039	19113	15011
$\frac{1}{2}$	54408	42732	16002	12568	$\frac{1}{2}$	65220	51224	19182	15066
$\frac{3}{4}$	54623	42901	16066	12618	$\frac{3}{4}$	65455	51409	19252	15120
127	54839	43070	16129	12668	139	65691	51594	19321	15175
$\frac{1}{4}$	55055	43240	16193	12718	$\frac{1}{4}$	65928	51780	19391	15229
$\frac{1}{2}$	55271	43410	16256	12768	$\frac{1}{2}$	66165	51966	19460	15284
$\frac{3}{4}$	55488	43580	16320	12818	$\frac{3}{4}$	66402	52152	19530	15339

140 — 163 ³/₄WEIGHTS AND AREAS OF
SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square ■	Round ●	Square ▣	Round ●		Square ■	Round ●	Square ▣	Round ●
140	66640	52339	19600	15394	152	78554	61696	23104	18146
$\frac{1}{4}$	66878	52526	19670	15449	$\frac{1}{4}$	78812	61899	23180	18206
$\frac{1}{2}$	67117	52714	19740	15504	$\frac{1}{2}$	79071	62103	23256	18265
$\frac{3}{4}$	67356	52901	19811	15559	$\frac{3}{4}$	79331	62306	23333	18325
141	67595	53089	19881	15615	153	79591	62510	23409	18385
$\frac{1}{4}$	67835	53278	19952	15670	$\frac{1}{4}$	79851	62715	23486	18446
$\frac{1}{2}$	68076	53467	20022	15725	$\frac{1}{2}$	80112	62920	23562	18506
$\frac{3}{4}$	68316	53656	20093	15781	$\frac{3}{4}$	80373	63125	23639	18566
142	68558	53845	20164	15837	154	80634	63330	23716	18627
$\frac{1}{4}$	68799	54035	20235	15893	$\frac{1}{4}$	80896	63536	23793	18687
$\frac{1}{2}$	69041	54225	20306	15949	$\frac{1}{2}$	81159	63742	23870	18748
$\frac{3}{4}$	69284	54415	20378	16005	$\frac{3}{4}$	81422	63949	23948	18808
143	69527	54606	20449	16061	155	81685	64155	24025	18869
$\frac{1}{4}$	69770	54797	20521	16117	$\frac{1}{4}$	81949	64363	24103	18930
$\frac{1}{2}$	70014	54989	20592	16173	$\frac{1}{2}$	82213	64570	24180	18991
$\frac{3}{4}$	70258	55180	20664	16230	$\frac{3}{4}$	82477	64778	24258	19052
144	70502	55373	20736	16286	156	82742	64986	24336	19113
$\frac{1}{4}$	70747	55565	20808	16343	$\frac{1}{4}$	83008	65194	24414	19175
$\frac{1}{2}$	70993	55758	20880	16399	$\frac{1}{2}$	83274	65403	24492	19236
$\frac{3}{4}$	71239	55951	20953	16456	$\frac{3}{4}$	83540	65612	24571	19298
145	71485	56144	21025	16513	157	83807	65822	24649	19359
$\frac{1}{4}$	71732	56338	21098	16570	$\frac{1}{4}$	84074	66031	24728	19421
$\frac{1}{2}$	71979	56532	21170	16627	$\frac{1}{2}$	84341	66242	24806	19483
$\frac{3}{4}$	72226	56727	21243	16684	$\frac{3}{4}$	84609	66452	24885	19545
146	72474	56921	21316	16742	158	84878	66663	24964	19607
$\frac{1}{4}$	72723	57116	21389	16799	$\frac{1}{4}$	85146	66874	25043	19669
$\frac{1}{2}$	72972	57312	21462	16856	$\frac{1}{2}$	85416	67085	25122	19731
$\frac{3}{4}$	73221	57508	21536	16914	$\frac{3}{4}$	85685	67297	25202	19793
147	73471	57704	21609	16972	159	85955	67509	25281	19856
$\frac{1}{4}$	73721	57900	21683	17029	$\frac{1}{4}$	86226	67722	25361	19918
$\frac{1}{2}$	73971	58097	21756	17087	$\frac{1}{2}$	86497	67935	25440	19981
$\frac{3}{4}$	74222	58294	21830	17145	$\frac{3}{4}$	86768	68148	25520	20043
148	74474	58492	21904	17203	160	87040	68361	25600	20106
$\frac{1}{4}$	74725	58689	21978	17262	$\frac{1}{4}$	87312	68575	25680	20169
$\frac{1}{2}$	74978	58887	22052	17320	$\frac{1}{2}$	87585	68789	25760	20232
$\frac{3}{4}$	75230	59086	22127	17378	$\frac{3}{4}$	87858	69004	25841	20295
149	75483	59285	22201	17437	161	88131	69218	25921	20358
$\frac{1}{4}$	75737	59484	22276	17495	$\frac{1}{4}$	88405	69434	26002	20422
$\frac{1}{2}$	75991	59683	22350	17554	$\frac{1}{2}$	88680	69649	26082	20485
$\frac{3}{4}$	76245	59883	22425	17613	$\frac{3}{4}$	88954	69865	26163	20548
150	76500	60083	22500	17672	162	89230	70081	26244	20612
$\frac{1}{4}$	76755	60284	22575	17730	$\frac{1}{4}$	89505	70297	26325	20676
$\frac{1}{2}$	77011	60484	22650	17790	$\frac{1}{2}$	89781	70514	26406	20739
$\frac{3}{4}$	77267	60685	22726	17849	$\frac{3}{4}$	90058	70731	26488	20803
151	77523	60887	22801	17908	163	90335	70949	26569	20867
$\frac{1}{4}$	77780	61089	22877	17967	$\frac{1}{4}$	90612	71167	26651	20931
$\frac{1}{2}$	78038	61291	22952	18027	$\frac{1}{2}$	90890	71385	26732	20996
$\frac{3}{4}$	78295	61493	23028	18086	$\frac{3}{4}$	91168	71603	26814	21060

164—180

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS

Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.		Size or Diameter Inches	Weight, Lbs. per Ft.		Area, Sq. In.	
	Square ■	Round ●	Square ▣	Round ●		Square ■	Round ●	Square ▣	Round ●
164	91446	71822	26896	21124	172	100586	79000	29584	23235
$\frac{1}{4}$	91725	72041	26978	21189	$\frac{1}{4}$	100878	79230	29670	23303
$\frac{1}{2}$	92005	72261	27060	21253	$\frac{1}{2}$	101171	79460	29756	23371
$\frac{3}{4}$	92285	72480	27143	21318	$\frac{3}{4}$	101465	79690	29843	23438
165	92565	72701	27225	21383	173	101759	79921	29929	23506
$\frac{1}{4}$	92846	72921	27308	21447	$\frac{1}{4}$	102053	80152	30016	23574
$\frac{1}{2}$	93127	73142	27390	21512	$\frac{1}{2}$	102348	80384	30102	23642
$\frac{3}{4}$	93408	73363	27473	21577	$\frac{3}{4}$	102643	80615	30189	23710
166	93690	73584	27556	21642	174	102938	80848	30276	23779
$\frac{1}{4}$	93973	73806	27639	21708	$\frac{1}{4}$	103234	81080	30363	23847
$\frac{1}{2}$	94256	74028	27722	21773	$\frac{1}{2}$	103531	81313	30450	23916
$\frac{3}{4}$	94539	74251	27806	21838	$\frac{3}{4}$	103828	81546	30538	23984
167	94823	74474	27889	21904	175	104125	81780	30625	24053
$\frac{1}{4}$	95107	74697	27973	21970	$\frac{1}{4}$	104423	82013	30713	24122
$\frac{1}{2}$	95391	74920	28056	22035	$\frac{1}{2}$	104721	82248	30800	24190
$\frac{3}{4}$	95676	75144	28140	22101	$\frac{3}{4}$	105019	82482	30888	24259
168	95962	75368	28224	22167	176	105318	82717	30976	24328
$\frac{1}{4}$	96247	75593	28308	22233	$\frac{1}{4}$	105618	82952	31064	24398
$\frac{1}{2}$	96534	75817	28392	22299	$\frac{1}{2}$	105918	83188	31152	24467
$\frac{3}{4}$	96820	76042	28477	22365	$\frac{3}{4}$	106218	83423	31241	24536
169	97107	76268	28561	22432	177	106519	83660	31329	24606
$\frac{1}{4}$	97395	76494	28646	22498	$\frac{1}{4}$	106820	83896	31418	24675
$\frac{1}{2}$	97682	76720	28730	22565	$\frac{1}{2}$	107121	84133	31506	24745
$\frac{3}{4}$	97971	76946	28815	22631	$\frac{3}{4}$	107423	84370	31595	24815
170	98260	77173	28900	22698	178	107726	84607	31684	24885
$\frac{1}{4}$	98549	77400	28985	22765	$\frac{1}{4}$	108028	84845	31773	24955
$\frac{1}{2}$	98839	77628	29070	22832	$\frac{1}{2}$	108332	85083	31862	25025
$\frac{3}{4}$	99129	77856	29156	22899	$\frac{3}{4}$	108635	85322	31952	25095
171	99419	78084	29241	22966	179	108939	85561	32041	25165
$\frac{1}{4}$	99710	78312	29327	23033	$\frac{1}{4}$	109244	85800	32131	25235
$\frac{1}{2}$	100002	78541	29412	23100	$\frac{1}{2}$	109549	86039	32220	25306
$\frac{3}{4}$	100293	78770	29498	23168	$\frac{3}{4}$	109854	86279	32310	25376
					180	110160	86519	32400	25447

ALLOY STEELS

Part 6

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

$\frac{3}{8}$ — $\frac{21}{32}$
 $\frac{1}{2}$ — $2\frac{1}{4}$

Thick- ness Inches	Width, Inches									
	$\frac{3}{8}$	$1\frac{1}{32}$	$\frac{7}{16}$	$1\frac{5}{32}$	$\frac{1}{2}$	$1\frac{7}{32}$	$\frac{9}{16}$	$1\frac{9}{32}$	$\frac{5}{8}$	$2\frac{1}{32}$
$\frac{1}{32}$	.0398	.0432	.0465	.0498	.0531	.0564	.0598	.0631	.0664	.0697
$\frac{1}{16}$	.0797	.0863	.0930	.0996	.1063	.1129	.1195	.1262	.1328	.1395
$\frac{3}{32}$	.1195	.1295	.1395	.1494	.1594	.1693	.1793	.1893	.1992	.2092
$\frac{1}{8}$	.1594	.1727	.1859	.1992	.2125	.2258	.2391	.2523	.2656	.2789
$\frac{5}{32}$	.1992	.2158	.2324	.2490	.2656	.2822	.2988	.3154	.3320	.3486
$\frac{3}{16}$	.2391	.2590	.2789	.2988	.3188	.3387	.3586	.3785	.3984	.4184
$\frac{7}{32}$	.2789	.3021	.3254	.3486	.3719	.3951	.4184	.4416	.4648	.4881
$\frac{1}{4}$	.3188	.3453	.3719	.3984	.4250	.4516	.4781	.5047	.5313	.5578
$\frac{5}{16}$	.3984	.4316	.4648	.4980	.5313	.5645	.5977	.6309	.6641	.6973
$\frac{3}{8}$	.4781	.5180	.5578	.5977	.6375	.6773	.7172	.7570	.7969	.8367
$\frac{7}{16}$	.5578	.6043	.6508	.6973	.7438	.7902	.8367	.8832	.9297	.9762
$\frac{1}{2}$	.6375	.6906	.7438	.7969	.8500	.9031	.9563	1.0094	1.0625	1.1156
$\frac{9}{16}$	.7172	.7770	.8367	.8965	.9563	1.0160	1.0758	1.1355	1.1953	1.2551
$\frac{5}{8}$	.7969	.8633	.9297	.9961	1.0625	1.1289	1.1953	1.2617	1.3281	1.3945
$1\frac{1}{16}$	.8766	.9496	1.0227	1.0957	1.1688	1.2418	1.3148	1.3879	1.4609	1.5340
$\frac{3}{4}$	.9563	1.0359	1.1156	1.1953	1.2750	1.3547	1.4344	1.5141	1.5938	1.6734
$1\frac{1}{8}$	1.0359	1.1223	1.2086	1.2949	1.3813	1.4676	1.5539	1.6402	1.7266	1.8129
$\frac{7}{8}$	1.1156	1.2086	1.3016	1.3945	1.4875	1.5805	1.6734	1.7664	1.8594	1.9523
$1\frac{1}{2}$	1.1953	1.2949	1.3945	1.4941	1.5938	1.6934	1.7930	1.8926	1.9922	2.0918
1	1.2750	1.3813	1.4875	1.5938	1.7000	1.8063	1.9125	2.0188	2.1250	2.2313
$\frac{1}{8}$	1.4344	1.5539	1.6734	1.7930	1.9125	2.0320	2.1516	2.2711	2.3906	2.5102
$\frac{1}{4}$	1.5938	1.7266	1.8594	1.9922	2.1250	2.2578	2.3906	2.5234	2.6563	2.7891
$\frac{3}{8}$	1.7531	1.8992	2.0453	2.1914	2.3375	2.4836	2.6297	2.7758	2.9219	3.0680
$\frac{1}{2}$	1.9125	2.0719	2.2313	2.3906	2.5500	2.7094	2.8688	3.0281	3.1875	3.3469
$\frac{5}{8}$	2.0719	2.2445	2.4172	2.5898	2.7625	2.9352	3.1078	3.2805	3.4531	3.6258
$\frac{3}{4}$	2.2313	2.4172	2.6031	2.7891	2.9750	3.1609	3.3469	3.5328	3.7188	3.9047
$\frac{7}{8}$	2.3906	2.5898	2.7891	2.9883	3.1875	3.3867	3.5859	3.7852	3.9844	4.1836
2	2.5500	2.7625	2.9750	3.1875	3.4000	3.6125	3.8250	4.0375	4.2500	4.4625
$\frac{1}{8}$	2.7094	2.9352	3.1609	3.3867	3.6125	3.8383	4.0641	4.2898	4.5156	4.7414
$\frac{1}{4}$	2.8688	3.1078	3.3469	3.5859	3.8250	4.0641	4.3031	4.5422	4.7813	5.0203

$$\begin{array}{r} 11 \\ 16 \\ 1 \\ 32 \end{array} - \begin{array}{r} 31 \\ 32 \\ 2 \\ 4 \end{array}$$

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

Thick- ness Inches	Width, Inches									
	$1\frac{1}{16}$	$2\frac{3}{32}$	$\frac{3}{4}$	$2\frac{5}{32}$	$1\frac{3}{16}$	$2\frac{7}{32}$	$\frac{7}{8}$	$2\frac{9}{32}$	$1\frac{5}{16}$	$3\frac{1}{32}$
$\frac{1}{32}$	.0730	.0764	.0797	.0830	.0863	.0896	.0930	.0963	.0996	.1029
$\frac{1}{16}$	.1461	.1527	.1594	.1660	.1727	.1793	.1859	.1926	.1992	.2059
$\frac{3}{32}$	.2191	.2291	.2391	.2490	.2590	.2689	.2789	.2889	.2988	.3088
$\frac{1}{8}$	.2922	.3055	.3188	.3320	.3453	.3586	.3719	.3852	.3984	.4117
$\frac{5}{32}$	.3652	.3818	.3984	.4150	.4316	.4482	.4648	.4814	.4980	.5146
$\frac{3}{16}$	.4383	.4582	.4781	.4980	.5180	.5379	.5578	.5777	.5977	.6176
$\frac{7}{32}$	.5113	.5346	.5578	.5811	.6043	.6275	.6508	.6740	.6973	.7205
$\frac{1}{4}$	.5844	.6109	.6375	.6641	.6906	.7172	.7438	.7703	.7969	.8234
$\frac{5}{16}$	.7305	.7637	.7969	.8301	.8633	.8965	.9297	.9629	.9961	1.0293
$\frac{3}{8}$	.8766	.9164	.9563	.9961	1.0359	1.0758	1.1156	1.1555	1.1953	1.2352
$\frac{7}{16}$	1.0227	1.0691	1.1156	1.1621	1.2086	1.2551	1.3016	1.3480	1.3945	1.4410
$\frac{1}{2}$	1.1688	1.2219	1.2750	1.3281	1.3813	1.4344	1.4875	1.5406	1.5938	1.6469
$\frac{9}{16}$	1.3148	1.3746	1.4344	1.4941	1.5539	1.6137	1.6734	1.7332	1.7930	1.8527
$\frac{5}{8}$	1.4609	1.5273	1.5938	1.6602	1.7266	1.7930	1.8594	1.9258	1.9922	2.0586
$1\frac{1}{16}$	1.6070	1.6801	1.7531	1.8262	1.8992	1.9723	2.0453	2.1184	2.1914	2.2645
$\frac{3}{4}$	1.7531	1.8328	1.9125	1.9922	2.0719	2.1516	2.2313	2.3109	2.3906	2.4703
$1\frac{3}{16}$	1.8992	1.9855	2.0719	2.1582	2.2445	2.3309	2.4172	2.5035	2.5898	2.6762
$\frac{7}{8}$	2.0453	2.1383	2.2313	2.3242	2.4172	2.5102	2.6031	2.6961	2.7891	2.8820
$1\frac{5}{16}$	2.1914	2.2910	2.3906	2.4902	2.5898	2.6895	2.7891	2.8887	2.9883	3.0879
1	2.3375	2.4438	2.5500	2.6563	2.7625	2.8688	2.9750	3.0813	3.1875	3.2938
$\frac{1}{8}$	2.6297	2.7492	2.8688	2.9883	3.1078	3.2273	3.3469	3.4664	3.5859	3.7055
$\frac{1}{4}$	2.9219	3.0547	3.1875	3.3203	3.4531	3.5859	3.7188	3.8516	3.9844	4.1172
$\frac{3}{8}$	3.2141	3.3602	3.5063	3.6523	3.7984	3.9445	4.0906	4.2367	4.3828	4.5289
$\frac{1}{2}$	3.5063	3.6656	3.8250	3.9844	4.1438	4.3031	4.4625	4.6219	4.7813	4.9406
$\frac{5}{8}$	3.7984	3.9711	4.1438	4.3164	4.4891	4.6617	4.8344	5.0070	5.1797	5.3523
$\frac{3}{4}$	4.0906	4.2766	4.4625	4.6484	4.8344	5.0203	5.2063	5.3922	5.5781	5.7641
$\frac{7}{8}$	4.3828	4.5820	4.7813	4.9805	5.1797	5.3789	5.5781	5.7773	5.9766	6.1758
2	4.6750	4.8875	5.1000	5.3125	5.5250	5.7375	5.9500	6.1625	6.3750	6.5875
$\frac{1}{8}$	4.9672	5.1930	5.4188	5.6445	5.8703	6.0961	6.3219	6.5477	6.7734	6.9992
$\frac{1}{4}$	5.2594	5.4984	5.7375	5.9766	6.2156	6.4547	6.6938	6.9328	7.1719	7.4109

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

$$\begin{array}{r} 1-1\frac{9}{32} \\ 1-2\frac{1}{4} \end{array}$$

Thick- ness Inches	Width, Inches									
	1	1 $\frac{1}{32}$	1 $\frac{1}{16}$	1 $\frac{3}{32}$	1 $\frac{1}{8}$	1 $\frac{5}{32}$	1 $\frac{3}{16}$	1 $\frac{7}{32}$	1 $\frac{1}{4}$	1 $\frac{9}{32}$
1 $\frac{1}{32}$	.1063	.1096	.1129	.1162	.1195	.1229	.1262	.1295	.1328	.1361
1 $\frac{1}{16}$	.2125	.2191	.2258	.2324	.2391	.2457	.2523	.2590	.2656	.2723
3 $\frac{1}{32}$	.3188	.3287	.3387	.3486	.3586	.3686	.3785	.3885	.3984	.4084
1 $\frac{1}{8}$	.4250	.4383	.4516	.4648	.4781	.4914	.5047	.5180	.5313	.5445
5 $\frac{1}{32}$	.5313	.5479	.5645	.5811	.5977	.6143	.6309	.6475	.6641	.6807
3 $\frac{1}{16}$	.6375	.6574	.6773	.6973	.7172	.7371	.7570	.7770	.7969	.8168
7 $\frac{1}{32}$	.7438	.7670	.7902	.8135	.8367	.8600	.8832	.9064	.9297	.9529
1 $\frac{1}{4}$	.8500	.8766	.9031	.9297	.9563	.9828	1.0094	1.0359	1.0625	1.0891
5 $\frac{1}{16}$	1.0625	1.0957	1.1289	1.1621	1.1953	1.2285	1.2617	1.2949	1.3281	1.3613
3 $\frac{1}{8}$	1.2750	1.3148	1.3547	1.3945	1.4344	1.4742	1.5141	1.5539	1.5938	1.6336
7 $\frac{1}{16}$	1.4875	1.5340	1.5805	1.6270	1.6734	1.7199	1.7664	1.8129	1.8594	1.9059
1 $\frac{1}{2}$	1.7000	1.7531	1.8063	1.8594	1.9125	1.9656	2.0188	2.0719	2.1250	2.1781
9 $\frac{1}{16}$	1.9125	1.9723	2.0320	2.0918	2.1516	2.2113	2.2711	2.3309	2.3906	2.4504
5 $\frac{1}{8}$	2.1250	2.1914	2.2578	2.3242	2.3906	2.4570	2.5234	2.5898	2.6563	2.7227
11 $\frac{1}{16}$	2.3375	2.4105	2.4836	2.5566	2.6297	2.7027	2.7758	2.8488	2.9219	2.9949
3 $\frac{1}{4}$	2.5500	2.6297	2.7094	2.7891	2.8688	2.9484	3.0281	3.1078	3.1875	3.2672
13 $\frac{1}{16}$	2.7625	2.8488	2.9352	3.0215	3.1078	3.1941	3.2805	3.3668	3.4531	3.5395
7 $\frac{1}{8}$	2.9750	3.0680	3.1609	3.2539	3.3469	3.4398	3.5328	3.6258	3.7188	3.8117
15 $\frac{1}{16}$	3.1875	3.2871	3.3867	3.4863	3.5859	3.6855	3.7852	3.8848	3.9844	4.0840
1	3.4000	3.5063	3.6125	3.7188	3.8250	3.9313	4.0375	4.1438	4.2500	4.3563
1 $\frac{1}{8}$	3.8250	3.9445	4.0641	4.1836	4.3031	4.4227	4.5422	4.6617	4.7813	4.9008
1 $\frac{1}{4}$	4.2500	4.3828	4.5156	4.6484	4.7813	4.9141	5.0469	5.1797	5.3125	5.4453
3 $\frac{1}{8}$	4.6750	4.8211	4.9672	5.1133	5.2594	5.4055	5.5516	5.6977	5.8438	5.9898
1 $\frac{1}{2}$	5.1000	5.2594	5.4188	5.5781	5.7375	5.8969	6.0563	6.2156	6.3750	6.5344
5 $\frac{1}{8}$	5.5250	5.6977	5.8703	6.0430	6.2156	6.3883	6.5609	6.7336	6.9063	7.0789
3 $\frac{1}{4}$	5.9500	6.1359	6.3219	6.5078	6.6938	6.8797	7.0656	7.2516	7.4375	7.6234
7 $\frac{1}{8}$	6.3750	6.5742	6.7734	6.9727	7.1719	7.3711	7.5703	7.7695	7.9688	8.1680
2	6.8000	7.0125	7.2250	7.4375	7.6500	7.8625	8.0750	8.2875	8.5000	8.7125
1 $\frac{1}{8}$	7.2250	7.4508	7.6766	7.9023	8.1281	8.3539	8.5797	8.8055	9.0313	9.2570
1 $\frac{1}{4}$	7.6500	7.8891	8.1281	8.3672	8.6063	8.8453	9.0844	9.3234	9.5625	9.8016

$$\begin{array}{r} 1 \frac{5}{16} - 1 \frac{11}{16} \\ 1 \frac{1}{32} - 2 \frac{1}{4} \end{array}$$

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

Thick- ness Inches	Width, Inches									
	$1 \frac{5}{16}$	$1 \frac{11}{32}$	$1 \frac{3}{8}$	$1 \frac{13}{32}$	$1 \frac{7}{16}$	$1 \frac{15}{32}$	$1 \frac{1}{2}$	$1 \frac{9}{16}$	$1 \frac{5}{8}$	$1 \frac{11}{16}$
$\frac{1}{32}$	.139	.143	.146	.149	.153	.156	.159	.166	.173	.179
$\frac{1}{16}$	.279	.286	.292	.299	.305	.312	.319	.332	.345	.359
$\frac{3}{32}$	.418	.428	.438	.448	.458	.468	.478	.498	.518	.538
$\frac{1}{8}$	.558	.571	.584	.598	.611	.624	.638	.664	.691	.717
$\frac{5}{32}$	.697	.714	.730	.747	.764	.780	.797	.830	.863	.896
$\frac{3}{16}$	.837	.857	.877	.896	.916	.936	.956	.996	1.036	1.076
$\frac{7}{32}$	.976	.999	1.023	1.046	1.069	1.092	1.116	1.162	1.209	1.255
$\frac{1}{4}$	1.116	1.142	1.169	1.195	1.222	1.248	1.275	1.328	1.381	1.434
$\frac{5}{16}$	1.395	1.428	1.461	1.494	1.527	1.561	1.594	1.660	1.727	1.793
$\frac{3}{8}$	1.673	1.713	1.753	1.793	1.833	1.873	1.913	1.992	2.072	2.152
$\frac{7}{16}$	1.952	1.999	2.045	2.092	2.138	2.185	2.231	2.324	2.417	2.510
$\frac{1}{2}$	2.231	2.284	2.338	2.391	2.444	2.497	2.550	2.656	2.763	2.869
$\frac{9}{16}$	2.510	2.570	2.630	2.689	2.749	2.809	2.869	2.988	3.108	3.227
$\frac{5}{8}$	2.789	2.855	2.922	2.988	3.055	3.121	3.188	3.320	3.453	3.586
$\frac{11}{16}$	3.068	3.141	3.214	3.287	3.360	3.433	3.506	3.652	3.798	3.945
$\frac{3}{4}$	3.347	3.427	3.506	3.586	3.666	3.745	3.825	3.984	4.144	4.303
$\frac{13}{16}$	3.626	3.712	3.798	3.885	3.971	4.057	4.144	4.316	4.489	4.662
$\frac{7}{8}$	3.905	3.998	4.091	4.184	4.277	4.370	4.463	4.648	4.834	5.020
$\frac{15}{16}$	4.184	4.283	4.383	4.482	4.582	4.682	4.781	4.980	5.180	5.379
1	4.463	4.569	4.675	4.781	4.888	4.994	5.100	5.313	5.525	5.738
$\frac{1}{8}$	5.020	5.140	5.259	5.379	5.498	5.618	5.738	5.977	6.216	6.455
$\frac{1}{4}$	5.578	5.711	5.844	5.977	6.109	6.242	6.375	6.641	6.906	7.172
$\frac{3}{8}$	6.136	6.282	6.428	6.574	6.720	6.866	7.013	7.305	7.597	7.889
$\frac{1}{2}$	6.694	6.853	7.013	7.172	7.331	7.491	7.650	7.969	8.288	8.606
$\frac{5}{8}$	7.252	7.424	7.597	7.770	7.942	8.115	8.288	8.633	8.978	9.323
$\frac{3}{4}$	7.809	7.995	8.181	8.367	8.553	8.739	8.925	9.297	9.669	10.041
$\frac{7}{8}$	8.367	8.566	8.766	8.965	9.164	9.363	9.563	9.961	10.359	10.758
2	8.925	9.138	9.350	9.563	9.775	9.988	10.200	10.625	11.050	11.475
$\frac{1}{8}$	9.483	9.709	9.934	10.160	10.386	10.612	10.838	11.289	11.741	12.192
$\frac{1}{4}$	10.041	10.280	10.519	10.758	10.997	11.236	11.475	11.953	12.431	12.909

FLAT BAR STEEL

$$1 \frac{3}{4} - 2 \frac{5}{16}$$

$$1 \frac{1}{32} - 2 \frac{1}{4}$$

WEIGHT PER LINEAR FOOT, POUNDS

Thick- ness Inches	Width, Inches									
	1 $\frac{3}{4}$	1 $\frac{13}{16}$	1 $\frac{7}{8}$	1 $\frac{15}{16}$	2	2 $\frac{1}{16}$	2 $\frac{1}{8}$	2 $\frac{3}{16}$	2 $\frac{1}{4}$	2 $\frac{5}{16}$
$\frac{1}{32}$	.186	.193	.199	.206	.213	.219	.226	.232	.239	.246
$\frac{1}{16}$	.372	.385	.398	.412	.425	.438	.452	.465	.478	.491
$\frac{3}{32}$	.558	.578	.598	.618	.638	.657	.677	.697	.717	.737
$\frac{1}{8}$	.744	.770	.797	.823	.850	.877	.903	.930	.956	.983
$\frac{5}{32}$	.930	.963	.996	1.029	1.063	1.096	1.129	1.162	1.195	1.229
$\frac{3}{16}$	1.116	1.155	1.195	1.235	1.275	1.315	1.355	1.395	1.434	1.474
$\frac{7}{32}$	1.302	1.348	1.395	1.441	1.488	1.534	1.580	1.627	1.673	1.720
$\frac{1}{4}$	1.488	1.541	1.594	1.647	1.700	1.753	1.806	1.859	1.913	1.966
$\frac{5}{16}$	1.859	1.926	1.992	2.059	2.125	2.191	2.258	2.324	2.391	2.457
$\frac{3}{8}$	2.231	2.311	2.391	2.470	2.550	2.630	2.709	2.789	2.869	2.948
$\frac{7}{16}$	2.603	2.696	2.789	2.882	2.975	3.068	3.161	3.254	3.347	3.440
$\frac{1}{2}$	2.975	3.081	3.188	3.294	3.400	3.506	3.613	3.719	3.825	3.931
$\frac{9}{16}$	3.347	3.466	3.586	3.705	3.825	3.945	4.064	4.184	4.303	4.423
$\frac{5}{8}$	3.719	3.852	3.984	4.117	4.250	4.383	4.516	4.648	4.781	4.914
$\frac{11}{16}$	4.091	4.237	4.383	4.529	4.675	4.821	4.967	5.113	5.259	5.405
$\frac{3}{4}$	4.463	4.622	4.781	4.941	5.100	5.259	5.419	5.578	5.738	5.897
$\frac{13}{16}$	4.834	5.007	5.180	5.352	5.525	5.698	5.870	6.043	6.216	6.388
$\frac{7}{8}$	5.206	5.392	5.578	5.764	5.950	6.136	6.322	6.508	6.694	6.880
$\frac{15}{16}$	5.578	5.777	5.977	6.176	6.375	6.574	6.773	6.973	7.172	7.371
1	5.950	6.163	6.375	6.588	6.800	7.013	7.225	7.438	7.650	7.863
$\frac{1}{8}$	6.694	6.933	7.172	7.411	7.650	7.889	8.128	8.367	8.606	8.845
$\frac{1}{4}$	7.438	7.703	7.969	8.234	8.500	8.766	9.031	9.297	9.563	9.828
$\frac{3}{8}$	8.181	8.473	8.766	9.058	9.350	9.642	9.934	10.227	10.519	10.811
$\frac{1}{2}$	8.925	9.244	9.563	9.881	10.200	10.519	10.838	11.156	11.475	11.794
$\frac{5}{8}$	9.669	10.014	10.359	10.705	11.050	11.395	11.741	12.086	12.431	12.777
$\frac{3}{4}$	10.413	10.784	11.156	11.528	11.900	12.272	12.644	13.016	13.388	13.759
$\frac{7}{8}$	11.156	11.555	11.953	12.352	12.750	13.148	13.547	13.945	14.344	14.742
2	11.900	12.325	12.750	13.175	13.600	14.025	14.450	14.875	15.300	15.725
$\frac{1}{8}$	12.644	13.095	13.547	13.998	14.450	14.902	15.353	15.805	16.256	16.708
$\frac{1}{4}$	13.388	13.866	14.344	14.822	15.300	15.778	16.256	16.734	17.213	17.691

$$\frac{2\frac{3}{8}}{\frac{1}{32}} - \frac{2\frac{15}{16}}{2\frac{1}{4}}$$

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

Thick- ness Inches	Width, Inches									
	$2\frac{3}{8}$	$2\frac{7}{16}$	$2\frac{1}{2}$	$2\frac{9}{16}$	$2\frac{5}{8}$	$2\frac{11}{16}$	$2\frac{3}{4}$	$2\frac{13}{16}$	$2\frac{7}{8}$	$2\frac{15}{16}$
$\frac{1}{32}$	.252	.259	.266	.272	.279	.286	.292	.299	.305	.312
$\frac{1}{16}$	.505	.518	.531	.545	.558	.571	.584	.598	.611	.624
$\frac{3}{32}$	.757	.777	.797	.817	.837	.857	.877	.896	.916	.936
$\frac{1}{8}$	1.009	1.036	1.063	1.089	1.116	1.142	1.169	1.195	1.222	1.248
$\frac{5}{32}$	1.262	1.295	1.328	1.361	1.395	1.428	1.461	1.494	1.527	1.561
$\frac{3}{16}$	1.514	1.554	1.594	1.634	1.673	1.713	1.753	1.793	1.833	1.873
$\frac{7}{32}$	1.766	1.813	1.859	1.906	1.952	1.999	2.045	2.092	2.138	2.185
$\frac{1}{4}$	2.019	2.072	2.125	2.178	2.231	2.284	2.338	2.391	2.444	2.497
$\frac{5}{16}$	2.523	2.590	2.656	2.723	2.789	2.855	2.922	2.988	3.055	3.121
$\frac{3}{8}$	3.028	3.108	3.188	3.267	3.347	3.427	3.506	3.586	3.666	3.745
$\frac{7}{16}$	3.533	3.626	3.719	3.812	3.905	3.998	4.091	4.184	4.277	4.370
$\frac{1}{2}$	4.038	4.144	4.250	4.356	4.463	4.569	4.675	4.781	4.888	4.994
$\frac{9}{16}$	4.542	4.662	4.781	4.901	5.020	5.140	5.259	5.379	5.498	5.618
$\frac{5}{8}$	5.047	5.180	5.313	5.445	5.578	5.711	5.844	5.977	6.109	6.242
$\frac{11}{16}$	5.552	5.698	5.844	5.990	6.136	6.282	6.428	6.574	6.720	6.866
$\frac{3}{4}$	6.056	6.216	6.375	6.534	6.694	6.853	7.013	7.172	7.331	7.491
$\frac{13}{16}$	6.561	6.734	6.906	7.079	7.252	7.424	7.597	7.770	7.942	8.115
$\frac{7}{8}$	7.066	7.252	7.438	7.623	7.809	7.995	8.181	8.367	8.553	8.739
$\frac{15}{16}$	7.570	7.770	7.969	8.168	8.367	8.566	8.766	8.965	9.164	9.363
1	8.075	8.288	8.500	8.713	8.925	9.138	9.350	9.563	9.775	9.988
$\frac{1}{8}$	9.084	9.323	9.563	9.802	10.041	10.280	10.519	10.758	10.997	11.236
$\frac{1}{4}$	10.094	10.359	10.625	10.891	11.156	11.422	11.688	11.953	12.219	12.484
$\frac{3}{8}$	11.103	11.395	11.688	11.980	12.272	12.564	12.856	13.148	13.441	13.733
$\frac{1}{2}$	12.113	12.431	12.750	13.069	13.388	13.706	14.025	14.344	14.663	14.981
$\frac{5}{8}$	13.122	13.467	13.813	14.158	14.503	14.848	15.194	15.539	15.884	16.230
$\frac{3}{4}$	14.131	14.503	14.875	15.247	15.619	15.991	16.363	16.734	17.106	17.478
$\frac{7}{8}$	15.141	15.539	15.938	16.336	16.734	17.133	17.531	17.930	18.328	18.727
2	16.150	16.575	17.000	17.425	17.850	18.275	18.700	19.125	19.550	19.975
$\frac{1}{8}$	17.159	17.611	18.063	18.514	18.966	19.417	19.869	20.320	20.772	21.223
$\frac{1}{4}$	18.169	18.647	19.125	19.603	20.081	20.559	21.038	21.516	21.994	22.472

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

$$3 - 3\frac{9}{16}$$

$$\frac{1}{32} - 2\frac{1}{4}$$

Thick- ness Inches	Width, Inches									
	3	3 $\frac{1}{16}$	3 $\frac{1}{8}$	3 $\frac{3}{16}$	3 $\frac{1}{4}$	3 $\frac{5}{16}$	3 $\frac{3}{8}$	3 $\frac{7}{16}$	3 $\frac{1}{2}$	3 $\frac{9}{16}$
$\frac{1}{32}$	.319	.325	.332	.339	.345	.352	.359	.365	.372	.379
$\frac{1}{16}$	.638	.651	.664	.677	.691	.704	.717	.730	.744	.757
$\frac{3}{32}$	.956	.976	.996	1.016	1.036	1.056	1.076	1.096	1.116	1.136
$\frac{1}{8}$	1.275	1.302	1.328	1.355	1.381	1.408	1.434	1.461	1.488	1.514
$\frac{5}{32}$	1.594	1.627	1.660	1.693	1.727	1.760	1.793	1.826	1.859	1.893
$\frac{3}{16}$	1.913	1.952	1.992	2.032	2.072	2.112	2.152	2.191	2.231	2.271
$\frac{7}{32}$	2.231	2.278	2.324	2.371	2.417	2.464	2.510	2.557	2.603	2.650
$\frac{1}{4}$	2.550	2.603	2.656	2.709	2.763	2.816	2.869	2.922	2.975	3.028
$\frac{5}{16}$	3.188	3.254	3.320	3.387	3.453	3.520	3.586	3.652	3.719	3.785
$\frac{3}{8}$	3.825	3.905	3.984	4.064	4.144	4.223	4.303	4.383	4.463	4.542
$\frac{7}{16}$	4.463	4.555	4.648	4.741	4.834	4.927	5.020	5.113	5.206	5.299
$\frac{1}{2}$	5.100	5.206	5.313	5.419	5.525	5.631	5.738	5.844	5.950	6.056
$\frac{9}{16}$	5.738	5.857	5.977	6.096	6.216	6.335	6.455	6.574	6.694	6.813
$\frac{5}{8}$	6.375	6.508	6.641	6.773	6.906	7.039	7.172	7.305	7.438	7.570
$\frac{11}{16}$	7.013	7.159	7.305	7.451	7.597	7.743	7.889	8.035	8.181	8.327
$\frac{3}{4}$	7.650	7.809	7.969	8.128	8.288	8.447	8.606	8.766	8.925	9.084
$\frac{13}{16}$	8.288	8.460	8.633	8.805	8.978	9.151	9.323	9.496	9.669	9.841
$\frac{7}{8}$	8.925	9.111	9.297	9.483	9.669	9.855	10.041	10.227	10.413	10.598
$\frac{15}{16}$	9.563	9.762	9.961	10.160	10.359	10.559	10.758	10.957	11.156	11.355
1	10.200	10.413	10.625	10.838	11.050	11.263	11.475	11.688	11.900	12.113
$\frac{1}{8}$	11.475	11.714	11.953	12.192	12.431	12.670	12.909	13.148	13.388	13.627
$\frac{1}{4}$	12.750	13.016	13.281	13.547	13.813	14.078	14.344	14.609	14.875	15.141
$\frac{3}{8}$	14.025	14.317	14.609	14.902	15.194	15.486	15.778	16.070	16.363	16.655
$\frac{1}{2}$	15.300	15.619	15.938	16.256	16.575	16.894	17.213	17.531	17.850	18.169
$\frac{5}{8}$	16.575	16.920	17.266	17.611	17.956	18.302	18.647	18.992	19.338	19.683
$\frac{3}{4}$	17.850	18.222	18.594	18.966	19.338	19.709	20.081	20.453	20.825	21.197
$\frac{7}{8}$	19.125	19.523	19.922	20.320	20.719	21.117	21.516	21.914	22.313	22.711
2	20.400	20.825	21.250	21.675	22.100	22.525	22.950	23.375	23.800	24.225
$\frac{1}{8}$	21.675	22.127	22.578	23.030	23.481	23.933	24.384	24.836	25.288	25.739
$\frac{1}{4}$	22.950	23.428	23.906	24.384	24.863	25.341	25.819	26.297	26.775	27.253

$$\frac{3}{8} - \frac{4}{16}$$

$$\frac{1}{32} - \frac{2}{4}$$

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

Thick- ness Inches	Width, Inches									
	$3\frac{5}{8}$	$3\frac{11}{16}$	$3\frac{3}{4}$	$3\frac{13}{16}$	$3\frac{7}{8}$	$3\frac{15}{16}$	4	$4\frac{1}{16}$	$4\frac{1}{8}$	$4\frac{3}{16}$
$\frac{1}{32}$	.385	.392	.398	.405	.412	.418	.425	.432	.438	.445
$\frac{1}{16}$	.770	.784	.797	.810	.823	.837	.850	.863	.877	.890
$\frac{3}{32}$	1.155	1.175	1.195	1.215	1.235	1.255	1.275	1.295	1.315	1.335
$\frac{1}{8}$	1.541	1.567	1.594	1.620	1.647	1.673	1.700	1.727	1.753	1.780
$\frac{5}{32}$	1.926	1.959	1.992	2.025	2.059	2.092	2.125	2.158	2.191	2.225
$\frac{3}{16}$	2.311	2.351	2.391	2.430	2.470	2.510	2.550	2.590	2.630	2.670
$\frac{7}{32}$	2.696	2.743	2.789	2.836	2.882	2.929	2.975	3.021	3.068	3.114
$\frac{1}{4}$	3.081	3.134	3.188	3.241	3.294	3.347	3.400	3.453	3.506	3.559
$\frac{5}{16}$	3.852	3.918	3.984	4.051	4.117	4.184	4.250	4.316	4.383	4.449
$\frac{3}{8}$	4.622	4.702	4.781	4.861	4.941	5.020	5.100	5.180	5.259	5.339
$\frac{7}{16}$	5.392	5.485	5.578	5.671	5.764	5.857	5.950	6.043	6.136	6.229
$\frac{1}{2}$	6.163	6.269	6.375	6.481	6.588	6.694	6.800	6.906	7.013	7.119
$\frac{9}{16}$	6.933	7.052	7.172	7.291	7.411	7.531	7.650	7.770	7.889	8.009
$\frac{5}{8}$	7.703	7.836	7.969	8.102	8.234	8.367	8.500	8.633	8.766	8.898
$\frac{11}{16}$	8.473	8.620	8.766	8.912	9.058	9.204	9.350	9.496	9.642	9.788
$\frac{3}{4}$	9.244	9.403	9.563	9.722	9.881	10.041	10.200	10.359	10.519	10.678
$\frac{13}{16}$	10.014	10.187	10.359	10.532	10.705	10.877	11.050	11.223	11.395	11.568
$\frac{7}{8}$	10.784	10.970	11.156	11.342	11.528	11.714	11.900	12.086	12.272	12.458
$\frac{15}{16}$	11.555	11.754	11.953	12.152	12.352	12.551	12.750	12.949	13.148	13.348
1	12.325	12.538	12.750	12.963	13.175	13.388	13.600	13.813	14.025	14.238
$\frac{1}{8}$	13.866	14.105	14.344	14.583	14.822	15.061	15.300	15.539	15.778	16.017
$\frac{1}{4}$	15.406	15.672	15.938	16.203	16.469	16.734	17.000	17.266	17.531	17.797
$\frac{3}{8}$	16.947	17.239	17.531	17.823	18.116	18.408	18.700	18.992	19.284	19.577
$\frac{1}{2}$	18.488	18.806	19.125	19.444	19.763	20.081	20.400	20.719	21.038	21.356
$\frac{5}{8}$	20.028	20.373	20.719	21.064	21.409	21.755	22.100	22.445	22.791	23.136
$\frac{3}{4}$	21.569	21.941	22.313	22.684	23.056	23.428	23.800	24.172	24.544	24.916
$\frac{7}{8}$	23.109	23.508	23.906	24.305	24.703	25.102	25.500	25.898	26.297	26.695
2	24.650	25.075	25.500	25.925	26.350	26.775	27.200	27.625	28.050	28.475
$\frac{1}{8}$	26.191	26.642	27.094	27.545	27.997	28.448	28.900	29.352	29.803	30.255
$\frac{1}{4}$	27.731	28.209	28.688	29.166	29.644	30.122	30.600	31.078	31.556	32.034

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

$4\frac{1}{4}$ — $4\frac{7}{8}$
 $\frac{1}{32}$ — $2\frac{1}{4}$

Thick- ness Inches	Width, Inches									
	$4\frac{1}{4}$	$4\frac{5}{16}$	$4\frac{3}{8}$	$4\frac{7}{16}$	$4\frac{1}{2}$	$4\frac{9}{16}$	$4\frac{5}{8}$	$4\frac{11}{16}$	$4\frac{3}{4}$	$4\frac{7}{8}$
$\frac{1}{32}$	.452	.458	.465	.471	.478	.485	.491	.498	.505	.518
$\frac{1}{16}$	.903	.916	.930	.943	.956	.970	.983	.996	1.009	1.036
$\frac{3}{32}$	1.355	1.375	1.395	1.414	1.434	1.454	1.474	1.494	1.514	1.554
$\frac{1}{8}$	1.806	1.833	1.859	1.886	1.913	1.939	1.966	1.992	2.019	2.072
$\frac{5}{32}$	2.258	2.291	2.324	2.357	2.391	2.424	2.457	2.490	2.523	2.590
$\frac{3}{16}$	2.709	2.749	2.789	2.829	2.869	2.909	2.948	2.988	3.028	3.108
$\frac{7}{32}$	3.161	3.207	3.254	3.300	3.347	3.393	3.440	3.486	3.533	3.626
$\frac{1}{4}$	3.613	3.666	3.719	3.772	3.825	3.878	3.931	3.984	4.038	4.144
$\frac{5}{16}$	4.516	4.582	4.648	4.715	4.781	4.848	4.914	4.980	5.047	5.180
$\frac{3}{8}$	5.419	5.498	5.578	5.658	5.738	5.817	5.897	5.977	6.056	6.216
$\frac{7}{16}$	6.322	6.415	6.508	6.601	6.694	6.787	6.880	6.973	7.066	7.252
$\frac{1}{2}$	7.225	7.331	7.438	7.544	7.650	7.756	7.863	7.969	8.075	8.288
$\frac{9}{16}$	8.128	8.248	8.367	8.487	8.606	8.726	8.845	8.965	9.084	9.323
$\frac{5}{8}$	9.031	9.164	9.297	9.430	9.563	9.695	9.828	9.961	10.094	10.359
$\frac{11}{16}$	9.934	10.080	10.227	10.373	10.519	10.665	10.811	10.957	11.103	11.395
$\frac{3}{4}$	10.838	10.997	11.156	11.316	11.475	11.634	11.794	11.953	12.113	12.431
$\frac{13}{16}$	11.741	11.913	12.086	12.259	12.431	12.604	12.777	12.949	13.122	13.467
$\frac{7}{8}$	12.644	12.830	13.016	13.202	13.388	13.573	13.759	13.945	14.131	14.503
$\frac{15}{16}$	13.547	13.746	13.945	14.145	14.344	14.543	14.742	14.941	15.141	15.539
1	14.450	14.663	14.875	15.088	15.300	15.513	15.725	15.938	16.150	16.575
$\frac{1}{8}$	16.256	16.495	16.734	16.973	17.213	17.452	17.691	17.930	18.169	18.647
$\frac{1}{4}$	18.063	18.328	18.594	18.859	19.125	19.391	19.656	19.922	20.188	20.719
$\frac{3}{8}$	19.869	20.161	20.453	20.745	21.038	21.330	21.622	21.914	22.206	22.791
$\frac{1}{2}$	21.675	21.994	22.313	22.631	22.950	23.269	23.588	23.906	24.225	24.863
$\frac{5}{8}$	23.481	23.827	24.172	24.517	24.863	25.208	25.553	25.898	26.244	26.934
$\frac{3}{4}$	25.288	25.659	26.031	26.403	26.775	27.147	27.519	27.891	28.263	29.006
$\frac{7}{8}$	27.094	27.492	27.891	28.289	28.688	29.086	29.484	29.883	30.281	31.078
2	28.900	29.325	29.750	30.175	30.600	31.025	31.450	31.875	32.300	33.150
$\frac{1}{8}$	30.706	31.158	31.609	32.061	32.513	32.964	33.416	33.867	34.319	35.222
$\frac{1}{4}$	32.513	32.991	33.469	33.947	34.425	34.903	35.381	35.859	36.338	37.294

$$5-6\frac{1}{8}$$

$$\frac{1}{32}-2\frac{1}{4}$$

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

Thick- ness Inches	Width, Inches									
	5	5 $\frac{1}{8}$	5 $\frac{1}{4}$	5 $\frac{3}{8}$	5 $\frac{1}{2}$	5 $\frac{5}{8}$	5 $\frac{3}{4}$	5 $\frac{7}{8}$	6	6 $\frac{1}{8}$
$\frac{1}{32}$	.531	.545	.558	.571	.584	.598	.611	.624	.638	.651
$\frac{1}{16}$	1.063	1.089	1.116	1.142	1.169	1.195	1.222	1.248	1.275	1.302
$\frac{3}{32}$	1.594	1.634	1.673	1.713	1.753	1.793	1.833	1.873	1.913	1.952
$\frac{1}{8}$	2.125	2.178	2.231	2.284	2.338	2.391	2.444	2.497	2.550	2.603
$\frac{5}{32}$	2.656	2.723	2.789	2.855	2.922	2.988	3.055	3.121	3.188	3.254
$\frac{3}{16}$	3.188	3.267	3.347	3.427	3.506	3.586	3.666	3.745	3.825	3.905
$\frac{7}{32}$	3.719	3.812	3.905	3.998	4.091	4.184	4.277	4.370	4.463	4.555
$\frac{1}{4}$	4.250	4.356	4.463	4.569	4.675	4.781	4.888	4.994	5.100	5.206
$\frac{5}{16}$	5.313	5.445	5.578	5.711	5.844	5.977	6.109	6.242	6.375	6.508
$\frac{3}{8}$	6.375	6.534	6.694	6.853	7.013	7.172	7.331	7.491	7.650	7.809
$\frac{7}{16}$	7.438	7.623	7.809	7.995	8.181	8.367	8.553	8.739	8.925	9.111
$\frac{1}{2}$	8.500	8.713	8.925	9.138	9.350	9.563	9.775	9.988	10.200	10.413
$\frac{9}{16}$	9.563	9.802	10.041	10.280	10.519	10.758	10.997	11.236	11.475	11.714
$\frac{5}{8}$	10.625	10.891	11.156	11.422	11.688	11.953	12.219	12.484	12.750	13.016
$\frac{11}{16}$	11.688	11.980	12.272	12.564	12.856	13.148	13.441	13.733	14.025	14.317
$\frac{3}{4}$	12.750	13.069	13.388	13.706	14.025	14.344	14.663	14.981	15.300	15.619
$\frac{13}{16}$	13.813	14.158	14.503	14.848	15.194	15.539	15.884	16.230	16.575	16.920
$\frac{7}{8}$	14.875	15.247	15.619	15.991	16.363	16.734	17.106	17.478	17.850	18.222
$\frac{15}{16}$	15.938	16.336	16.734	17.133	17.531	17.930	18.328	18.727	19.125	19.523
1	17.000	17.425	17.850	18.275	18.700	19.125	19.550	19.975	20.400	20.825
$\frac{1}{8}$	19.125	19.603	20.081	20.559	21.038	21.516	21.994	22.472	22.950	23.428
$\frac{1}{4}$	21.250	21.781	22.313	22.844	23.375	23.906	24.438	24.969	25.500	26.031
$\frac{3}{8}$	23.375	23.959	24.544	25.128	25.713	26.297	26.881	27.466	28.050	28.634
$\frac{1}{2}$	25.500	26.138	26.775	27.413	28.050	28.688	29.325	29.963	30.600	31.238
$\frac{5}{8}$	27.625	28.316	29.006	29.697	30.388	31.078	31.769	32.459	33.150	33.841
$\frac{3}{4}$	29.750	30.494	31.238	31.981	32.725	33.469	34.213	34.956	35.700	36.444
$\frac{7}{8}$	31.875	32.672	33.469	34.266	35.063	35.859	36.656	37.453	38.250	39.047
2	34.000	34.850	35.700	36.550	37.400	38.250	39.100	39.950	40.800	41.650
$\frac{1}{8}$	36.125	37.028	37.931	38.834	39.738	40.641	41.544	42.447	43.350	44.253
$\frac{1}{4}$	38.250	39.206	40.163	41.119	42.075	43.031	43.988	44.944	45.900	46.856

ALLOY STEELS

Part 6

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

6 $\frac{1}{4}$ — 7 $\frac{3}{8}$
1 $\frac{1}{32}$ — 2 $\frac{1}{4}$

Thick- ness Inches	Width, Inches									
	6 $\frac{1}{4}$	6 $\frac{3}{8}$	6 $\frac{1}{2}$	6 $\frac{5}{8}$	6 $\frac{3}{4}$	6 $\frac{7}{8}$	7	7 $\frac{1}{8}$	7 $\frac{1}{4}$	7 $\frac{3}{8}$
$\frac{1}{32}$	.664	.677	.691	.704	.717	.730	.744	.757	.770	.784
$\frac{1}{16}$	1.328	1.355	1.381	1.408	1.434	1.461	1.488	1.514	1.541	1.567
$\frac{3}{32}$	1.992	2.032	2.072	2.112	2.152	2.191	2.231	2.271	2.311	2.351
$\frac{1}{8}$	2.656	2.709	2.763	2.816	2.869	2.922	2.975	3.028	3.081	3.134
$\frac{5}{32}$	3.320	3.387	3.453	3.520	3.586	3.652	3.719	3.785	3.852	3.918
$\frac{3}{16}$	3.984	4.064	4.144	4.223	4.303	4.383	4.463	4.542	4.622	4.702
$\frac{7}{32}$	4.648	4.741	4.834	4.927	5.020	5.113	5.206	5.299	5.392	5.485
$\frac{1}{4}$	5.313	5.419	5.525	5.631	5.738	5.844	5.950	6.056	6.163	6.269
$\frac{5}{16}$	6.641	6.773	6.906	7.039	7.172	7.305	7.438	7.570	7.703	7.836
$\frac{3}{8}$	7.969	8.128	8.288	8.447	8.606	8.766	8.925	9.084	9.244	9.403
$\frac{7}{16}$	9.297	9.483	9.669	9.855	10.041	10.227	10.413	10.598	10.784	10.970
$\frac{1}{2}$	10.625	10.838	11.050	11.263	11.475	11.688	11.900	12.113	12.325	12.538
$\frac{9}{16}$	11.953	12.192	12.431	12.670	12.909	13.148	13.388	13.627	13.866	14.105
$\frac{5}{8}$	13.281	13.547	13.813	14.078	14.344	14.609	14.875	15.141	15.406	15.672
$\frac{11}{16}$	14.609	14.902	15.194	15.486	15.778	16.070	16.363	16.655	16.947	17.239
$\frac{3}{4}$	15.938	16.256	16.575	16.894	17.213	17.531	17.850	18.169	18.488	18.806
$\frac{13}{16}$	17.266	17.611	17.956	18.302	18.647	18.992	19.338	19.683	20.028	20.373
$\frac{7}{8}$	18.594	18.966	19.338	19.709	20.081	20.453	20.825	21.197	21.569	21.941
$\frac{15}{16}$	19.922	20.320	20.719	21.117	21.516	21.914	22.313	22.711	23.109	23.508
1	21.250	21.675	22.100	22.525	22.950	23.375	23.800	24.225	24.650	25.075
$\frac{1}{8}$	23.906	24.384	24.863	25.341	25.819	26.297	26.775	27.253	27.731	28.209
$\frac{1}{4}$	26.563	27.094	27.625	28.156	28.688	29.219	29.750	30.281	30.813	31.344
$\frac{3}{8}$	29.219	29.803	30.388	30.972	31.556	32.141	32.725	33.309	33.894	34.478
$\frac{1}{2}$	31.875	32.513	33.150	33.788	34.425	35.063	35.700	36.338	36.975	37.613
$\frac{5}{8}$	34.531	35.222	35.913	36.603	37.294	37.984	38.675	39.366	40.056	40.747
$\frac{3}{4}$	37.188	37.931	38.675	39.419	40.163	40.906	41.650	42.394	43.138	43.881
$\frac{7}{8}$	39.844	40.641	41.438	42.234	43.031	43.828	44.625	45.422	46.219	47.016
2	42.500	43.350	44.200	45.050	45.900	46.750	47.600	48.450	49.300	50.150
$\frac{1}{8}$	45.156	46.059	46.963	47.866	48.769	49.672	50.575	51.478	52.381	53.284
$\frac{1}{4}$	47.813	48.769	49.725	50.681	51.638	52.594	53.550	54.506	55.463	56.419

$$\begin{array}{r} 7\frac{1}{2} - 8\frac{5}{8} \\ 1\frac{1}{32} - 2\frac{1}{4} \end{array}$$

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

Thick- ness Inches	Width, Inches									
	7½	7⅝	7¾	7⅞	8	8⅛	8¼	8⅜	8½	8⅝
1⅜	.797	.810	.823	.837	.850	.863	.877	.890	.903	.916
1⅞	1.594	1.620	1.647	1.673	1.700	1.727	1.753	1.780	1.806	1.833
2⅜	2.391	2.430	2.470	2.510	2.550	2.590	2.630	2.670	2.709	2.749
2⅞	3.188	3.241	3.294	3.347	3.400	3.453	3.506	3.559	3.613	3.666
3⅜	3.984	4.051	4.117	4.184	4.250	4.316	4.383	4.449	4.516	4.582
3⅞	4.781	4.861	4.941	5.020	5.100	5.180	5.259	5.339	5.419	5.498
4⅜	5.578	5.671	5.764	5.857	5.950	6.043	6.136	6.229	6.322	6.415
4⅞	6.375	6.481	6.588	6.694	6.800	6.906	7.013	7.119	7.225	7.331
5⅜	7.969	8.102	8.234	8.367	8.500	8.633	8.766	8.898	9.031	9.164
5⅞	9.563	9.722	9.881	10.041	10.200	10.359	10.519	10.678	10.838	10.997
6⅜	11.156	11.342	11.528	11.714	11.900	12.086	12.272	12.458	12.644	12.830
6⅞	12.750	12.963	13.175	13.388	13.600	13.813	14.025	14.238	14.450	14.663
7⅜	14.344	14.583	14.822	15.061	15.300	15.539	15.778	16.017	16.256	16.495
7⅞	15.938	16.203	16.469	16.734	17.000	17.266	17.531	17.797	18.063	18.328
8⅜	17.531	17.823	18.116	18.408	18.700	18.992	19.284	19.577	19.869	20.161
8⅞	19.125	19.444	19.763	20.081	20.400	20.719	21.038	21.356	21.675	21.994
9⅜	20.719	21.064	21.409	21.755	22.100	22.445	22.791	23.136	23.481	23.827
9⅞	22.313	22.684	23.056	23.428	23.800	24.172	24.544	24.916	25.288	25.659
10⅜	23.906	24.305	24.703	25.102	25.500	25.898	26.297	26.695	27.094	27.492
1	25.500	25.925	26.350	26.775	27.200	27.625	28.050	28.475	28.900	29.325
1⅜	28.688	29.166	29.644	30.122	30.600	31.078	31.556	32.034	32.513	32.991
1⅞	31.875	32.406	32.938	33.469	34.000	34.531	35.063	35.594	36.125	36.656
2⅜	35.063	35.647	36.231	36.816	37.400	37.984	38.569	39.153	39.738	40.322
2⅞	38.250	38.888	39.525	40.163	40.800	41.438	42.075	42.713	43.350	43.988
3⅜	41.438	42.128	42.819	43.509	44.200	44.891	45.581	46.272	46.963	47.653
3⅞	44.625	45.369	46.113	46.856	47.600	48.344	49.088	49.831	50.575	51.319
4⅜	47.813	48.609	49.406	50.203	51.000	51.797	52.594	53.391	54.188	54.984
2	51.000	51.850	52.700	53.550	54.400	55.250	56.100	56.950	57.800	58.650
1⅜	54.188	55.091	55.994	56.897	57.800	58.703	59.606	60.509	61.413	62.316
1⅞	57.375	58.331	59.288	60.244	61.200	62.156	63.113	64.069	65.025	65.981

FLAT BAR STEEL

$$8\frac{3}{4} - 10$$

$$\frac{1}{32} - 2\frac{1}{4}$$

WEIGHT PER LINEAR FOOT, POUNDS

Thick- ness Inches	Width, Inches									
	8 $\frac{3}{4}$	8 $\frac{7}{8}$	9	9 $\frac{1}{8}$	9 $\frac{1}{4}$	9 $\frac{3}{8}$	9 $\frac{1}{2}$	9 $\frac{5}{8}$	9 $\frac{3}{4}$	10
$\frac{1}{32}$	.930	.943	.956	.970	.983	.996	1.009	1.023	1.036	1.063
$\frac{1}{16}$	1.859	1.886	1.913	1.939	1.966	1.992	2.019	2.045	2.072	2.125
$\frac{3}{32}$	2.789	2.829	2.869	2.909	2.948	2.988	3.028	3.068	3.108	3.188
$\frac{1}{8}$	3.719	3.772	3.825	3.878	3.931	3.984	4.038	4.091	4.144	4.250
$\frac{5}{32}$	4.648	4.715	4.781	4.848	4.914	4.980	5.047	5.113	5.180	5.313
$\frac{3}{16}$	5.578	5.658	5.738	5.817	5.897	5.977	6.056	6.136	6.216	6.375
$\frac{7}{32}$	6.508	6.601	6.694	6.787	6.880	6.973	7.066	7.159	7.252	7.437
$\frac{1}{4}$	7.438	7.544	7.650	7.756	7.863	7.969	8.075	8.181	8.288	8.500
$\frac{5}{16}$	9.297	9.430	9.563	9.695	9.828	9.961	10.094	10.227	10.359	10.625
$\frac{3}{8}$	11.156	11.316	11.475	11.634	11.794	11.953	12.113	12.272	12.431	12.750
$\frac{7}{16}$	13.016	13.202	13.388	13.573	13.759	13.945	14.131	14.317	14.503	14.875
$\frac{1}{2}$	14.875	15.088	15.300	15.513	15.725	15.938	16.150	16.363	16.575	17.000
$\frac{9}{16}$	16.734	16.973	17.213	17.452	17.691	17.930	18.169	18.408	18.647	19.125
$\frac{5}{8}$	18.594	18.859	19.125	19.391	19.656	19.922	20.188	20.453	20.719	21.250
$\frac{11}{16}$	20.453	20.745	21.038	21.330	21.622	21.914	22.206	22.498	22.791	23.375
$\frac{3}{4}$	22.313	22.631	22.950	23.269	23.588	23.906	24.225	24.544	24.863	25.500
$\frac{13}{16}$	24.172	24.517	24.863	25.208	25.553	25.898	26.244	26.589	26.934	27.625
$\frac{7}{8}$	26.031	26.403	26.775	27.147	27.519	27.891	28.263	28.634	29.006	29.750
$\frac{15}{16}$	27.891	28.289	28.688	29.086	29.484	29.883	30.281	30.680	31.078	31.875
1	29.750	30.175	30.600	31.025	31.450	31.875	32.300	32.725	33.150	34.000
$\frac{1}{8}$	33.469	33.947	34.425	34.903	35.381	35.859	36.338	36.816	37.294	38.250
$\frac{1}{4}$	37.188	37.719	38.250	38.781	39.313	39.844	40.375	40.906	41.438	42.500
$\frac{3}{8}$	40.906	41.491	42.075	42.659	43.244	43.828	44.413	44.997	45.581	46.750
$\frac{1}{2}$	44.625	45.263	45.900	46.538	47.175	47.813	48.450	49.088	49.725	51.000
$\frac{5}{8}$	48.344	49.034	49.725	50.416	51.106	51.797	52.488	53.178	53.869	55.250
$\frac{3}{4}$	52.063	52.806	53.550	54.294	55.038	55.781	56.525	57.269	58.013	59.500
$\frac{7}{8}$	55.781	56.578	57.375	58.172	58.969	59.766	60.563	61.359	62.156	63.750
2	59.500	60.350	61.200	62.050	62.900	63.750	64.600	65.450	66.300	68.000
$\frac{1}{8}$	63.219	64.122	65.025	65.928	66.831	67.734	68.638	69.541	70.444	72.250
$\frac{1}{4}$	66.938	67.894	68.850	69.806	70.763	71.719	72.675	73.631	74.588	76.500

$10\frac{1}{4}$ —12
 $\frac{1}{32}$ — $2\frac{1}{4}$

FLAT BAR STEEL

WEIGHT PER LINEAR FOOT, POUNDS

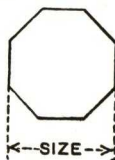
Thick- ness Inches	Width, Inches							
	$10\frac{1}{4}$	$10\frac{1}{2}$	$10\frac{3}{4}$	11	$11\frac{1}{4}$	$11\frac{1}{2}$	$11\frac{3}{4}$	12
$\frac{1}{32}$	1.089	1.116	1.142	1.169	1.195	1.222	1.248	1.275
$\frac{1}{16}$	2.178	2.231	2.284	2.338	2.391	2.444	2.497	2.550
$\frac{3}{32}$	3.267	3.347	3.427	3.506	3.586	3.666	3.745	3.825
$\frac{1}{8}$	4.356	4.463	4.569	4.675	4.781	4.888	4.994	5.100
$\frac{5}{32}$	5.445	5.578	5.711	5.844	5.977	6.109	6.242	6.375
$\frac{3}{16}$	6.534	6.694	6.853	7.013	7.172	7.331	7.491	7.650
$\frac{7}{32}$	7.623	7.809	7.995	8.181	8.367	8.553	8.739	8.925
$\frac{1}{4}$	8.713	8.925	9.138	9.350	9.563	9.775	9.988	10.200
$\frac{5}{16}$	10.891	11.156	11.422	11.688	11.953	12.219	12.484	12.750
$\frac{3}{8}$	13.069	13.388	13.706	14.025	14.344	14.663	14.981	15.300
$\frac{7}{16}$	15.247	15.619	15.991	16.363	16.734	17.106	17.478	17.850
$\frac{1}{2}$	17.425	17.850	18.275	18.700	19.125	19.550	19.975	20.400
$\frac{9}{16}$	19.603	20.081	20.559	21.038	21.516	21.994	22.472	22.950
$\frac{5}{8}$	21.781	22.313	22.844	23.375	23.906	24.438	24.969	25.500
$\frac{11}{16}$	23.959	24.544	25.128	25.713	26.297	26.881	27.466	28.050
$\frac{3}{4}$	26.138	26.775	27.413	28.050	28.688	29.325	29.963	30.600
$\frac{13}{16}$	28.316	29.006	29.697	30.388	31.078	31.769	32.459	33.150
$\frac{7}{8}$	30.494	31.238	31.981	32.725	33.469	34.213	34.956	35.700
$\frac{15}{16}$	32.672	33.469	34.266	35.063	35.859	36.656	37.453	38.250
1	34.850	35.700	36.550	37.400	38.250	39.100	39.950	40.800
$\frac{1}{8}$	39.206	40.163	41.119	42.075	43.031	43.988	44.944	45.900
$\frac{1}{4}$	43.563	44.625	45.688	46.750	47.813	48.875	49.938	51.000
$\frac{3}{8}$	47.919	49.088	50.256	51.425	52.594	53.763	54.931	56.100
$\frac{1}{2}$	52.275	53.550	54.825	56.100	57.375	58.650	59.925	61.200
$\frac{5}{8}$	56.631	58.013	59.394	60.775	62.156	63.538	64.919	66.300
$\frac{3}{4}$	60.988	62.475	63.963	65.450	66.938	68.425	69.913	71.400
$\frac{7}{8}$	65.344	66.938	68.531	70.125	71.719	73.313	74.906	76.500
2	69.700	71.400	73.100	74.800	76.500	78.200	79.900	81.600
$\frac{1}{8}$	74.056	75.863	77.669	79.475	81.281	83.088	84.894	86.700
$\frac{1}{4}$	78.413	80.325	82.238	84.150	86.063	87.975	89.888	91.800

WEIGHTS OF HEXAGON BARS



Size Inches	Pounds per Foot	Size Inches	Pounds per Foot	Size Inches	Pounds per Foot	Size Inches	Pounds per Foot
$\frac{1}{64}$	.0007	$\frac{27}{32}$	2.0962	$\frac{25}{32}$	13.6901	$\frac{315}{32}$	35.4287
$\frac{1}{32}$	.0029	$\frac{7}{8}$	2.2544	$\frac{23}{16}$	14.0898	$\frac{31}{2}$	36.0699
$\frac{3}{64}$	.0065			$\frac{27}{32}$	14.4953		
$\frac{1}{16}$	.0115	$\frac{29}{32}$	2.4183	$\frac{21}{4}$	14.9065	$\frac{317}{32}$	36.7169
		$\frac{15}{16}$	2.5879			$\frac{39}{16}$	37.3697
$\frac{5}{64}$	.0180	$\frac{31}{32}$	2.7633	$\frac{29}{32}$	15.3234	$\frac{319}{32}$	38.0281
$\frac{3}{32}$	.0259	1	2.9445	$\frac{25}{16}$	15.7461	$\frac{35}{8}$	38.6924
$\frac{7}{64}$	.0352			$\frac{211}{32}$	16.1745		
$\frac{1}{8}$	.0460	$\frac{11}{32}$	3.1314	$\frac{23}{8}$	16.6087	$\frac{321}{32}$	39.3624
		$\frac{11}{16}$	3.3240			$\frac{311}{16}$	40.0381
$\frac{9}{64}$	.0582	$\frac{13}{32}$	3.5225	$\frac{213}{32}$	17.0487	$\frac{323}{32}$	40.7196
$\frac{5}{32}$	.0719	$\frac{11}{8}$	3.7266	$\frac{27}{16}$	17.4944	$\frac{33}{4}$	41.4068
$\frac{11}{64}$	.0870			$\frac{215}{32}$	17.9458		
$\frac{3}{16}$	.1035	$\frac{15}{32}$	3.9365	$\frac{21}{2}$	18.4030	$\frac{325}{32}$	42.0998
		$\frac{13}{16}$	4.1522			$\frac{313}{16}$	42.7985
$\frac{13}{64}$	.1215	$\frac{17}{32}$	4.3736	$\frac{217}{32}$	18.8660	$\frac{327}{32}$	43.5030
$\frac{7}{32}$	.1409	$\frac{11}{4}$	4.6008	$\frac{29}{16}$	19.3347	$\frac{37}{8}$	44.2133
$\frac{15}{64}$	.1617			$\frac{219}{32}$	19.8091		
$\frac{1}{4}$	.1840	$\frac{19}{32}$	4.8337	$\frac{25}{8}$	20.2893	$\frac{329}{32}$	44.9293
		$\frac{15}{16}$	5.0723			$\frac{315}{16}$	45.6510
$\frac{17}{64}$	.2078	$\frac{111}{32}$	5.3168	$\frac{221}{32}$	20.7753	$\frac{331}{32}$	46.3785
$\frac{9}{32}$	.2329	$\frac{13}{8}$	5.5669	$\frac{211}{16}$	21.2670	4	47.1118
$\frac{19}{64}$	.2595			$\frac{223}{32}$	21.7645		
$\frac{5}{16}$	.2875	$\frac{113}{32}$	5.8228	$\frac{23}{4}$	22.2677	$\frac{41}{8}$	50.102
		$\frac{17}{16}$	6.0845			$\frac{41}{4}$	53.185
$\frac{21}{64}$	.3170	$\frac{115}{32}$	6.3519	$\frac{225}{32}$	22.7766	$\frac{43}{8}$	56.359
$\frac{11}{32}$	.3479	$\frac{11}{2}$	6.6251	$\frac{213}{16}$	23.2913	$\frac{41}{2}$	59.626
$\frac{23}{64}$	.3803			$\frac{227}{32}$	23.8118		
$\frac{3}{8}$	.4141	$\frac{117}{32}$	6.9040	$\frac{27}{8}$	24.3380	$\frac{45}{8}$	62.984
		$\frac{19}{16}$	7.1887			$\frac{43}{4}$	66.435
$\frac{25}{64}$	.4493	$\frac{119}{32}$	7.4791	$\frac{229}{32}$	24.8700		
$\frac{13}{32}$	.4860	$\frac{15}{8}$	7.7753	$\frac{215}{16}$	25.4077	5	73.612
$\frac{27}{64}$	.5241			$\frac{231}{32}$	25.9512	$\frac{51}{4}$	81.157
$\frac{7}{16}$	.5636	$\frac{121}{32}$	8.0772	3	26.5004	$\frac{51}{2}$	89.071
		$\frac{111}{16}$	8.3849			$\frac{53}{4}$	97.352
$\frac{29}{64}$	.6046	$\frac{123}{32}$	8.6983	$\frac{31}{32}$	27.0553		
$\frac{15}{32}$	.6470	$\frac{13}{4}$	9.0175	$\frac{31}{16}$	27.6160	6	106.001
$\frac{31}{64}$	.6908			$\frac{33}{32}$	28.1825	$\frac{61}{2}$	124.404
$\frac{1}{2}$	.7361	$\frac{125}{32}$	9.3424	$\frac{31}{8}$	28.7547		
		$\frac{113}{16}$	9.6731			7	144.280
$\frac{17}{32}$	.8310	$\frac{127}{32}$	10.0095	$\frac{35}{32}$	29.3327	$\frac{71}{2}$	165.627
$\frac{9}{16}$	.9317	$\frac{17}{8}$	10.3517	$\frac{33}{16}$	29.9164		
$\frac{19}{32}$	1.0380			$\frac{37}{32}$	30.5059	8	188.447
$\frac{5}{8}$	1.1502	$\frac{129}{32}$	10.6996	$\frac{37}{16}$	31.1011	$\frac{81}{2}$	212.739
		$\frac{115}{16}$	11.0533				
$\frac{21}{32}$	1.2681	$\frac{131}{32}$	11.4128	$\frac{39}{32}$	31.7021	9	238.503
$\frac{11}{16}$	1.3917	2	11.7779	$\frac{35}{16}$	32.3088	$\frac{91}{2}$	265.740
$\frac{23}{32}$	1.5211			$\frac{311}{32}$	32.9213		
$\frac{3}{4}$	1.6563	$\frac{21}{32}$	12.1489	$\frac{33}{8}$	33.5395	10	294.449
		$\frac{21}{16}$	12.5256				
$\frac{25}{32}$	1.7972	$\frac{23}{32}$	12.9080	$\frac{313}{32}$	34.1635	11	356.283
$\frac{13}{16}$	1.9438	$\frac{21}{8}$	13.2962	$\frac{37}{16}$	34.7932	12	424.006

WEIGHTS OF OCTAGON BARS



Size Inches	Pounds per Foot	Size Inches	Pounds per Foot	Size Inches	Pounds per Foot	Size Inches	Pounds per Foot
$\frac{1}{64}$	.0007	$\frac{27}{32}$	2.0052	$\frac{25}{32}$	13.0958	$\frac{315}{32}$	33.8906
$\frac{1}{32}$	.0028	$\frac{7}{8}$	2.1565	$\frac{23}{16}$	13.4781	$3\frac{1}{2}$	34.5040
$\frac{3}{64}$	.0062			$\frac{27}{32}$	13.8660		
$\frac{1}{16}$	.0110	$\frac{29}{32}$	2.3133	$2\frac{1}{4}$	14.2593	$\frac{317}{32}$	35.1229
		$\frac{15}{16}$	2.4756			$\frac{39}{16}$	35.7473
$\frac{5}{64}$	.0172	$\frac{31}{32}$	2.6434	$\frac{29}{32}$	14.6582	$\frac{319}{32}$	36.3772
$\frac{3}{32}$	.0248	1	2.8167	$\frac{25}{16}$	15.0625	$3\frac{5}{8}$	37.0126
$\frac{7}{64}$	.0337			$\frac{211}{32}$	15.4723		
$\frac{1}{8}$	.0440	$\frac{11}{32}$	2.9954	$\frac{23}{8}$	15.8877	$\frac{321}{32}$	37.6535
		$\frac{11}{16}$	3.1797			$\frac{311}{16}$	38.2999
$\frac{9}{64}$	.0557	$\frac{13}{32}$	3.3695	$\frac{213}{32}$	16.3085	$\frac{323}{32}$	38.9518
$\frac{5}{32}$	.0688	$\frac{11}{8}$	3.5648	$\frac{27}{16}$	16.7349	$3\frac{3}{4}$	39.6092
$\frac{11}{64}$	.0832			$\frac{215}{32}$	17.1667		
$\frac{3}{16}$	.0990	$\frac{15}{32}$	3.7656	$2\frac{1}{2}$	17.6041	$\frac{325}{32}$	40.2721
		$\frac{13}{16}$	3.9719			$\frac{313}{16}$	40.9405
$\frac{13}{64}$	.1162	$\frac{17}{32}$	4.1837	$\frac{217}{32}$	18.0469	$\frac{327}{32}$	41.6144
$\frac{7}{32}$	.1348	$\frac{1}{4}$	4.4010	$\frac{29}{16}$	18.4953	$3\frac{7}{8}$	42.2938
$\frac{15}{64}$	.1547			$\frac{219}{32}$	18.9492		
$\frac{1}{4}$	.1760	$\frac{19}{32}$	4.6238	$2\frac{5}{8}$	19.4085	$\frac{329}{32}$	42.9787
		$\frac{15}{16}$	4.8521			$\frac{319}{16}$	43.6692
$\frac{17}{64}$	.1987	$\frac{111}{32}$	5.0859	$\frac{221}{32}$	19.8734	$\frac{331}{32}$	44.3651
$\frac{9}{32}$	.2228	$\frac{13}{8}$	5.3252	$\frac{211}{16}$	20.3437	4	45.0665
$\frac{19}{64}$	.2482			$\frac{223}{32}$	20.8196		
$\frac{5}{16}$	.2751	$\frac{113}{32}$	5.5700	$\frac{23}{4}$	21.3010	$\frac{41}{8}$	47.927
		$\frac{17}{16}$	5.8204			$\frac{41}{4}$	50.876
$\frac{21}{64}$	.3033	$\frac{115}{32}$	6.0762	$\frac{225}{32}$	21.7878	$\frac{43}{8}$	53.912
$\frac{11}{32}$	.3328	$\frac{1}{2}$	6.3375	$\frac{213}{16}$	22.2802	$\frac{41}{2}$	57.037
$\frac{23}{64}$	.3638			$\frac{227}{32}$	22.7780		
$\frac{3}{8}$	.3961	$\frac{117}{32}$	6.6043	$\frac{27}{8}$	23.2814	$\frac{45}{8}$	60.250
		$\frac{9}{16}$	6.8766			$\frac{43}{4}$	63.551
$\frac{25}{64}$	.4298	$\frac{119}{32}$	7.1544	$\frac{229}{32}$	23.7903		
$\frac{13}{32}$	.4649	$\frac{1}{5/8}$	7.4377	$\frac{215}{16}$	24.3047	5	70.416
$\frac{27}{64}$	.5013			$\frac{231}{32}$	24.8245	$\frac{51}{4}$	77.634
$\frac{7}{16}$	.5391	$\frac{121}{32}$	7.7265	3	25.3499	$\frac{51}{2}$	85.204
		$\frac{111}{16}$	8.0209			$\frac{53}{4}$	93.126
$\frac{29}{64}$	.5783	$\frac{123}{32}$	8.3207	$\frac{31}{32}$	25.8808		
$\frac{15}{32}$	.6189	$\frac{1}{4}$	8.6260	$\frac{31}{16}$	26.4171	6	101.399
$\frac{31}{64}$	.6608			$\frac{33}{32}$	26.9590	$\frac{61}{2}$	119.004
$\frac{1}{2}$	.7042	$\frac{125}{32}$	8.9368	$\frac{31}{8}$	27.5064		
		$\frac{13}{16}$	9.2532			7	138.016
$\frac{17}{32}$	.7949	$\frac{127}{32}$	9.5750	$\frac{35}{32}$	28.0593	$\frac{71}{2}$	158.437
$\frac{9}{16}$	.8912	$\frac{1}{8}$	9.9023	$\frac{39}{16}$	28.6177		
$\frac{19}{32}$	.9930			$\frac{37}{32}$	29.1815	8	180.266
$\frac{5}{8}$	1.1003	$\frac{129}{32}$	10.2351	$\frac{31}{4}$	29.7509	$\frac{81}{2}$	203.503
		$\frac{115}{16}$	10.5735				
$\frac{21}{32}$	1.2130	$\frac{131}{32}$	10.9173	$\frac{39}{32}$	30.3258	9	228.149
$\frac{11}{16}$	1.3313	2	11.2666	$\frac{35}{16}$	30.9062	$\frac{91}{2}$	254.203
$\frac{23}{32}$	1.4551			$\frac{311}{32}$	31.4921		
$\frac{3}{4}$	1.5844	$\frac{21}{32}$	11.6215	$\frac{39}{8}$	32.0835	10	281.665
		$\frac{21}{16}$	11.9818				
$\frac{25}{32}$	1.7192	$\frac{23}{32}$	12.3476	$\frac{313}{32}$	32.6804	11	340.815
$\frac{13}{16}$	1.8594	$\frac{21}{8}$	12.7190	$\frac{317}{16}$	33.2827	12	405.598

No. 13— $\frac{5}{16}$
 $\frac{3}{8}$ — $2\frac{3}{16}$

WEIGHTS OF ROUND EDGE FLATS



POUNDS PER LINEAR FOOT

FACE MEASURE



Face Measure Inches	THICKNESS, B. W. G. AND INCHES									
	No. 13	No. 12	No. 11	No. 10	No. 9	No. 8	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
$\frac{3}{8}$	.132	.153	.170	.192	.215	.243	.178	.281	.393	.514
$\frac{7}{16}$	.152	.176	.196	.221	.246	.278	.204	.321	.446	.581
$\frac{1}{2}$	.172	.199	.221	.249	.278	.313	.231	.361	.499	.647
$\frac{9}{16}$	.192	.223	.247	.278	.309	.348	.258	.400	.552	.714
$\frac{5}{8}$	.213	.246	.272	.306	.341	.383	.284	.440	.605	.780
$\frac{11}{16}$	.233	.269	.298	.335	.372	.418	.311	.480	.659	.847
$\frac{3}{4}$	.253	.292	.323	.363	.403	.453	.337	.520	.712	.913
$\frac{13}{16}$	.273	.315	.349	.392	.435	.488	.364	.560	.765	.979
$\frac{7}{8}$	.293	.338	.374	.420	.466	.523	.390	.600	.818	1.046
$\frac{15}{16}$	.314	.362	.400	.448	.498	.558	.417	.639	.871	1.112
1	.334	.385	.425	.477	.529	.593	.444	.679	.924	1.179
$\frac{1}{16}$	.354	.408	.451	.505	.561	.628	.470	.719	.977	1.245
$\frac{1}{8}$	.374	.431	.476	.534	.592	.663	.497	.759	1.030	1.311
$\frac{3}{16}$	.394	.454	.502	.562	.624	.699	.523	.799	1.084	1.378
$\frac{1}{4}$	.414	.477	.527	.591	.655	.734	.550	.839	1.137	1.444
$\frac{5}{16}$	.435	.501	.553	.619	.686	.769	.576	.879	1.190	1.511
$\frac{3}{8}$	.455	.524	.578	.648	.718	.804	.603	.918	1.243	1.577
$\frac{7}{16}$	.475	.547	.604	.676	.749	.839	.629	.958	1.296	1.643
$\frac{1}{2}$	.495	.570	.629	.705	.781	.874	.656	.998	1.349	1.710
$\frac{9}{16}$	.515	.593	.655	.733	.812	.909	.683	1.038	1.402	1.776
$\frac{5}{8}$	.536	.616	.680	.762	.844	.944	.709	1.078	1.455	1.843
$\frac{11}{16}$	.556	.640	.706	.790	.875	.979	.736	1.118	1.509	1.909
$\frac{3}{4}$	.576	.663	.731	.819	.907	1.014	.762	1.157	1.562	1.975
$\frac{13}{16}$	.596	.686	.757	.847	.938	1.049	.789	1.197	1.615	2.042
$\frac{7}{8}$	.616	.709	.782	.876	.970	1.084	.815	1.237	1.668	2.108
$\frac{15}{16}$	.637	.732	.808	.904	1.001	1.119	.842	1.277	1.721	2.175
2	.657	.755	.833	.933	1.032	1.154	.869	1.317	1.774	2.241
$\frac{1}{16}$	.677	.778	.859	.961	1.064	1.189	.895	1.357	1.827	2.307
$\frac{1}{8}$	.697	.802	.884	.989	1.095	1.224	.922	1.396	1.880	2.374
$\frac{3}{16}$	.717	.825	.910	1.018	1.127	1.260	.948	1.436	1.934	2.440

To obtain Over-all Measure for any thickness, add to Face Measure the Increment given in table below for corresponding thickness.

THICKNESS, B. W. G. AND INCHES									
No. 13	No. 12	No. 11	No. 10	No. 9	No. 8	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
INCREMENT, INCHES									
.0475	.0545	.0600	.0670	.0740	.0825	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$

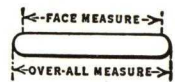
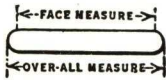
$\frac{3}{8}$ — 1
 $\frac{3}{8}$ — 2 $\frac{3}{16}$
 $\frac{3}{8}$

WEIGHTS OF ROUND EDGE FLATS

POUNDS PER LINEAR FOOT

FACE MEASURE

(Continued)



Face Measure Inches	THICKNESS, INCHES										
	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
$\frac{3}{8}$	.645	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
$\frac{7}{16}$	.725	.878	-----	-----	-----	-----	-----	-----	-----	-----	-----
$\frac{1}{2}$	.805	.971	1.147	-----	-----	-----	-----	-----	-----	-----	-----
$\frac{9}{16}$	.884	1.064	1.253	1.498	-----	-----	-----	-----	-----	-----	-----
$\frac{5}{8}$	.964	1.157	1.360	1.617	1.792	-----	-----	-----	-----	-----	-----
$\frac{11}{16}$	1.044	1.250	1.466	1.737	1.925	2.114	-----	-----	-----	-----	-----
$\frac{3}{4}$	1.123	1.343	1.572	1.856	2.058	2.260	2.462	-----	-----	-----	-----
$\frac{13}{16}$	1.203	1.436	1.678	1.976	2.191	2.406	2.621	2.964	-----	-----	-----
$\frac{7}{8}$	1.283	1.529	1.785	2.096	2.324	2.552	2.781	3.136	3.373	-----	-----
$\frac{15}{16}$	1.362	1.622	1.891	2.215	2.456	2.698	2.940	3.309	3.559	3.810	-----
1	1.442	1.715	1.997	2.335	2.589	2.844	3.099	3.482	3.745	4.009	4.273
$\frac{1}{16}$	1.522	1.808	2.103	2.454	2.722	2.990	3.259	3.654	3.931	4.209	4.486
$\frac{1}{8}$	1.601	1.901	2.210	2.574	2.855	3.136	3.418	3.827	4.117	4.408	4.698
$\frac{3}{16}$	1.681	1.994	2.316	2.693	2.988	3.282	3.577	4.000	4.303	4.607	4.911
$\frac{1}{4}$	1.761	2.087	2.422	2.813	3.120	3.428	3.737	4.172	4.489	4.806	5.123
$\frac{5}{16}$	1.841	2.180	2.528	2.932	3.253	3.575	3.896	4.345	4.675	5.005	5.336
$\frac{3}{8}$	1.920	2.273	2.635	3.052	3.386	3.721	4.056	4.518	4.861	5.205	5.548
$\frac{7}{16}$	2.000	2.366	2.741	3.171	3.519	3.867	4.215	4.690	5.047	5.404	5.761
$\frac{1}{2}$	2.080	2.459	2.847	3.291	3.652	4.013	4.374	4.863	5.233	5.603	5.973
$\frac{9}{16}$	2.159	2.552	2.953	3.410	3.784	4.159	4.534	5.036	5.419	5.802	6.186
$\frac{5}{8}$	2.239	2.645	3.060	3.530	3.917	4.305	4.693	5.208	5.605	6.002	6.398
$\frac{11}{16}$	2.319	2.738	3.166	3.649	4.050	4.451	4.852	5.381	5.791	6.201	6.611
$\frac{3}{4}$	2.398	2.831	3.272	3.769	4.183	4.597	5.012	5.554	5.977	6.400	6.823
$\frac{13}{16}$	2.478	2.924	3.378	3.888	4.316	4.743	5.171	5.726	6.163	6.599	7.036
$\frac{7}{8}$	2.558	3.016	3.485	4.008	4.449	4.889	5.331	5.899	6.348	6.798	7.248
$\frac{15}{16}$	2.637	3.109	3.591	4.128	4.581	5.035	5.490	6.072	6.534	6.998	7.461
2	2.717	3.202	3.697	4.247	4.714	5.182	5.649	6.244	6.720	7.197	7.673
$\frac{1}{16}$	2.797	3.295	3.803	4.367	4.847	5.328	5.809	6.417	6.906	7.396	7.886
$\frac{1}{8}$	2.876	3.388	3.910	4.486	4.980	5.474	5.968	6.590	7.092	7.595	8.098
$\frac{3}{16}$	2.956	3.481	4.016	4.606	5.113	5.620	6.127	6.762	7.278	7.795	8.311

To obtain Over-all Measure for any thickness, add to Face Measure the Increment given in table below for corresponding thickness.

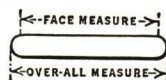
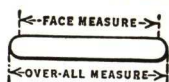
THICKNESS, INCHES										
$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
INCREMENT, INCHES										
$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$

No. 13 — $\frac{5}{16}$
2 $\frac{1}{4}$ — 6

WEIGHTS OF ROUND EDGE FLATS

POUNDS PER LINEAR FOOT
FACE MEASURE

(Continued)



Face Measure Inches	THICKNESS, B. W. G. AND INCHES									
	No. 13	No. 12	No. 11	No. 10	No. 9	No. 8	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
2 $\frac{1}{4}$	.737	.848	.935	1.046	1.158	1.295	.975	1.476	1.987	2.507
$\frac{5}{16}$	.758	.871	.961	1.075	1.190	1.330	1.001	1.516	2.040	2.573
$\frac{3}{8}$	.778	.894	.986	1.103	1.221	1.365	1.028	1.556	2.093	2.639
$\frac{7}{16}$	.798	.917	1.012	1.132	1.253	1.400	1.054	1.596	2.146	2.706
$\frac{1}{2}$	.818	.941	1.037	1.160	1.284	1.435	1.081	1.636	2.199	2.772
$\frac{5}{8}$	.859	.987	1.088	1.217	1.347	1.505	1.134	1.715	2.305	2.905
$\frac{3}{4}$	.899	1.033	1.139	1.274	1.410	1.575	1.187	1.795	2.412	3.038
$\frac{7}{8}$	.939	1.080	1.190	1.331	1.473	1.645	1.240	1.875	2.518	3.171
3	.980	1.126	1.241	1.388	1.536	1.715	1.294	1.954	2.624	3.304
$\frac{1}{8}$	-----	-----	-----	1.445	1.599	1.785	1.347	2.034	2.730	3.436
$\frac{1}{4}$	-----	-----	-----	1.502	1.661	1.856	1.400	2.114	2.837	3.569
$\frac{3}{8}$	-----	-----	-----	1.559	1.724	1.926	1.453	2.193	2.943	3.702
$\frac{1}{2}$	-----	-----	-----	1.616	1.787	1.996	1.506	2.273	3.049	3.835
$\frac{5}{8}$	-----	-----	-----	-----	-----	-----	-----	2.353	3.155	3.968
$\frac{3}{4}$	-----	-----	-----	-----	-----	-----	-----	2.432	3.262	4.100
$\frac{7}{8}$	-----	-----	-----	-----	-----	-----	-----	2.512	3.368	4.233
4	-----	-----	-----	-----	-----	-----	-----	2.592	3.474	4.366
$\frac{1}{8}$	-----	-----	-----	-----	-----	-----	-----	-----	3.580	4.499
$\frac{1}{4}$	-----	-----	-----	-----	-----	-----	-----	-----	3.687	4.632
$\frac{3}{8}$	-----	-----	-----	-----	-----	-----	-----	-----	3.793	4.764
$\frac{1}{2}$	-----	-----	-----	-----	-----	-----	-----	-----	3.899	4.897
$\frac{5}{8}$	-----	-----	-----	-----	-----	-----	-----	-----	4.005	5.030
$\frac{3}{4}$	-----	-----	-----	-----	-----	-----	-----	-----	4.112	5.163
$\frac{7}{8}$	-----	-----	-----	-----	-----	-----	-----	-----	4.218	5.296
5	-----	-----	-----	-----	-----	-----	-----	-----	4.324	5.429
$\frac{1}{8}$	-----	-----	-----	-----	-----	-----	-----	-----	4.430	5.561
$\frac{1}{4}$	-----	-----	-----	-----	-----	-----	-----	-----	4.537	5.694
$\frac{3}{8}$	-----	-----	-----	-----	-----	-----	-----	-----	4.643	5.827
$\frac{1}{2}$	-----	-----	-----	-----	-----	-----	-----	-----	4.749	5.960
$\frac{5}{8}$	-----	-----	-----	-----	-----	-----	-----	-----	4.855	6.093
$\frac{3}{4}$	-----	-----	-----	-----	-----	-----	-----	-----	4.962	6.225
$\frac{7}{8}$	-----	-----	-----	-----	-----	-----	-----	-----	5.068	6.358
6	-----	-----	-----	-----	-----	-----	-----	-----	5.174	6.491

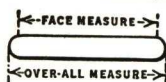
To obtain Over-all Measure for any thickness, add to Face Measure the Increment given in table below for corresponding thickness.

THICKNESS, B. W. G. AND INCHES									
No. 13	No. 12	No. 11	No. 10	No. 9	No. 8	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
.0475	.0545	.0600	.0670	.0740	.0825	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$

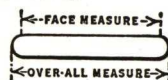
INCREMENT, INCHES

$\frac{3}{8}$ —1
 $2\frac{1}{4}$ —6

WEIGHTS OF ROUND EDGE FLATS



POUNDS PER LINEAR FOOT
 FACE MEASURE
 (Concluded)



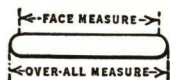
Face Measure Inches	THICKNESS, INCHES										
	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
$2\frac{1}{4}$	3.036	3.574	4.122	4.725	5.245	5.766	6.287	6.935	7.464	7.994	8.523
$\frac{5}{16}$	3.116	3.667	4.228	4.845	5.378	5.912	6.446	7.108	7.650	8.193	8.736
$\frac{3}{8}$	3.195	3.760	4.335	4.964	5.511	6.058	6.606	7.280	7.836	8.392	8.948
$\frac{7}{16}$	3.275	3.853	4.441	5.084	5.644	6.204	6.765	7.453	8.022	8.591	9.161
$\frac{1}{2}$	3.355	3.946	4.547	5.203	5.777	6.350	6.924	7.625	8.208	8.791	9.373
$\frac{5}{8}$	3.514	4.132	4.760	5.442	6.042	6.643	7.243	7.971	8.580	9.189	9.798
$\frac{3}{4}$	3.673	4.318	4.972	5.681	6.308	6.935	7.562	8.316	8.952	9.587	10.223
$\frac{7}{8}$	3.833	4.504	5.185	5.921	6.574	7.227	7.881	8.661	9.323	9.986	10.648
3	3.992	4.690	5.397	6.160	6.839	7.519	8.199	9.007	9.695	10.384	11.073
$\frac{1}{8}$	4.151	4.876	5.610	6.399	7.105	7.811	8.518	9.352	10.067	10.783	11.498
$\frac{1}{4}$	4.311	5.062	5.822	6.638	7.370	8.103	8.837	9.697	10.439	11.181	11.923
$\frac{3}{8}$	4.470	5.248	6.035	6.877	7.636	8.396	9.156	10.043	10.811	11.579	12.348
$\frac{1}{2}$	4.630	5.434	6.247	7.116	7.902	8.688	9.474	10.388	11.183	11.978	12.773
$\frac{5}{8}$	4.789	5.620	6.460	7.355	8.167	8.980	9.793	10.733	11.555	12.377	13.198
$\frac{3}{4}$	4.948	5.806	6.672	7.594	8.433	9.272	10.112	11.079	11.927	12.775	13.623
$\frac{7}{8}$	5.108	5.991	6.885	7.833	8.699	9.564	10.431	11.424	12.298	13.173	14.048
4	5.267	6.177	7.097	8.072	8.964	9.857	10.749	11.769	12.670	13.572	14.473
$\frac{1}{8}$	5.426	6.363	7.310	8.311	9.230	10.149	11.068	12.115	13.042	13.970	14.898
$\frac{1}{4}$	5.586	6.549	7.522	8.550	9.495	10.441	11.387	12.460	13.414	14.369	15.323
$\frac{3}{8}$	5.745	6.735	7.735	8.789	9.761	10.733	11.706	12.805	13.786	14.767	15.748
$\frac{1}{2}$	5.905	6.921	7.947	9.028	10.027	11.025	12.024	13.150	14.158	15.166	16.173
$\frac{5}{8}$	6.064	7.107	8.160	9.267	10.292	11.318	12.343	13.496	14.530	15.564	16.598
$\frac{3}{4}$	6.223	7.293	8.372	9.506	10.558	11.610	12.662	13.841	14.902	15.962	17.023
$\frac{7}{8}$	6.383	7.479	8.585	9.746	10.824	11.902	12.981	14.186	15.273	16.361	17.448
5	6.542	7.665	8.797	9.985	11.089	12.194	13.299	14.532	15.645	16.759	17.873
$\frac{1}{8}$	6.701	7.851	9.010	10.224	11.355	12.486	13.618	14.877	16.017	17.158	18.298
$\frac{1}{4}$	6.861	8.037	9.222	10.463	11.620	12.778	13.937	15.222	16.389	17.556	18.723
$\frac{3}{8}$	7.020	8.223	9.435	10.702	11.886	13.071	14.256	15.568	16.761	17.955	19.148
$\frac{1}{2}$	7.180	8.409	9.647	10.941	12.152	13.363	14.574	15.913	17.133	18.353	19.573
$\frac{5}{8}$	7.339	8.595	9.860	11.180	12.417	13.655	14.893	16.258	17.505	18.752	19.998
$\frac{3}{4}$	7.498	8.781	10.072	11.419	12.683	13.947	15.212	16.604	17.877	19.150	20.423
$\frac{7}{8}$	7.658	8.966	10.285	11.658	12.949	14.239	15.531	16.949	18.248	19.548	20.848
6	7.817	9.152	10.497	11.897	13.214	14.532	15.849	17.294	18.620	19.947	21.273

To obtain Over-all Measure for any thickness, add to Face Measure the Increment given in table below for corresponding thickness.

THICKNESS, INCHES										
$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
INCREMENT, INCHES										
$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$

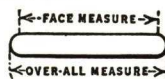
No. 13— $\frac{5}{16}$
 $\frac{3}{8}$ — $2\frac{3}{16}$

WEIGHTS OF ROUND EDGE FLATS



POUNDS PER LINEAR FOOT

OVER-ALL MEASURE



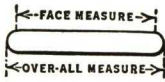
Over-all Measure Inches	THICKNESS, B. W. G. AND INCHES									
	No. 13	No. 12	No. 11	No. 10	No. 9	No. 8	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
$\frac{3}{8}$	.117	.133	.146	.162	.177	.196	.151	.221	.287	.348
$\frac{7}{16}$	.137	.156	.171	.190	.209	.232	.178	.261	.340	.415
$\frac{1}{2}$	.157	.179	.197	.219	.240	.267	.204	.301	.393	.481
$\frac{9}{16}$	.177	.202	.222	.247	.272	.302	.231	.341	.446	.548
$\frac{5}{8}$	.197	.226	.248	.276	.303	.337	.258	.380	.499	.614
$\frac{11}{16}$	.217	.249	.273	.304	.335	.372	.284	.420	.552	.680
$\frac{3}{4}$	.238	.272	.299	.333	.366	.407	.311	.460	.605	.747
$\frac{13}{16}$	.258	.295	.324	.361	.398	.442	.337	.500	.659	.813
$\frac{7}{8}$	.278	.318	.350	.389	.429	.477	.364	.540	.712	.880
$\frac{15}{16}$	.298	.341	.375	.418	.461	.512	.390	.580	.765	.946
1	.318	.365	.401	.446	.492	.547	.417	.620	.818	1.013
$\frac{1}{16}$	.339	.388	.426	.475	.523	.582	.444	.659	.871	1.079
$\frac{1}{8}$	.359	.411	.452	.503	.555	.617	.470	.699	.924	1.145
$\frac{3}{16}$	.379	.434	.477	.532	.586	.652	.497	.739	.977	1.212
$\frac{1}{4}$	.399	.457	.503	.560	.618	.687	.523	.779	1.030	1.278
$\frac{5}{16}$	.419	.480	.528	.589	.649	.722	.550	.819	1.084	1.345
$\frac{3}{8}$	.440	.503	.554	.617	.681	.757	.576	.859	1.137	1.411
$\frac{7}{16}$	.460	.527	.579	.646	.712	.793	.603	.898	1.190	1.477
$\frac{1}{2}$	.480	.550	.605	.674	.744	.828	.629	.938	1.243	1.544
$\frac{9}{16}$	.500	.573	.630	.703	.775	.863	.656	.978	1.296	1.610
$\frac{5}{8}$	.520	.596	.656	.731	.806	.898	.683	1.018	1.349	1.677
$\frac{11}{16}$	.540	.619	.681	.760	.838	.933	.709	1.058	1.402	1.743
$\frac{3}{4}$	.561	.642	.707	.788	.869	.968	.736	1.098	1.455	1.809
$\frac{13}{16}$	.581	.666	.732	.817	.901	1.003	.762	1.137	1.509	1.876
$\frac{7}{8}$	.601	.689	.758	.845	.932	1.038	.789	1.177	1.562	1.942
$\frac{15}{16}$	.621	.712	.783	.874	.964	1.073	.815	1.217	1.615	2.009
2	.641	.735	.809	.902	.995	1.108	.842	1.257	1.668	2.075
$\frac{1}{16}$	.662	.758	.834	.930	1.027	1.143	.869	1.297	1.721	2.141
$\frac{1}{8}$	.682	.781	.860	.959	1.058	1.178	.895	1.337	1.774	2.208
$\frac{3}{16}$	.702	.805	.885	.987	1.090	1.213	.922	1.377	1.827	2.274

To obtain Face Measure for any thickness, subtract from Over-all Measure the Increment given in table below for corresponding thickness.

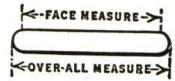
THICKNESS, B. W. G. AND INCHES									
No. 13	No. 12	No. 11	No. 10	No. 9	No. 8	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
INCREMENT, INCHES									
.0475	.0545	.0600	.0670	.0740	.0825	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$

3 — 1
8 — 2 $\frac{3}{16}$

WEIGHTS OF ROUND EDGE FLATS



POUNDS PER LINEAR FOOT
OVER-ALL MEASURE
(Continued)



Over-all Measure Inches	THICKNESS, INCHES										
	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
$\frac{3}{8}$	.406	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
$\frac{7}{16}$	.486	.553	-----	-----	-----	-----	-----	-----	-----	-----	-----
$\frac{1}{2}$	.566	.646	.722	-----	-----	-----	-----	-----	-----	-----	-----
$\frac{9}{16}$	.645	.739	.828	.900	-----	-----	-----	-----	-----	-----	-----
$\frac{5}{8}$	.725	.832	.935	1.020	1.128	-----	-----	-----	-----	-----	-----
$\frac{11}{16}$	.805	.925	1.041	1.139	1.261	1.383	-----	-----	-----	-----	-----
$\frac{3}{4}$	.884	1.018	1.147	1.259	1.394	1.529	1.665	-----	-----	-----	-----
$\frac{13}{16}$	.964	1.111	1.253	1.378	1.527	1.675	1.824	1.928	-----	-----	-----
$\frac{7}{8}$	1.044	1.204	1.360	1.498	1.659	1.821	1.984	2.100	2.258	-----	-----
$\frac{15}{16}$	1.123	1.297	1.466	1.617	1.792	1.968	2.143	2.273	2.444	2.615	-----
1	1.203	1.390	1.572	1.737	1.925	2.114	2.302	2.446	2.630	2.814	2.998
$\frac{1}{16}$	1.283	1.483	1.678	1.856	2.058	2.260	2.462	2.618	2.816	3.013	3.211
$\frac{1}{8}$	1.362	1.575	1.785	1.976	2.191	2.406	2.621	2.791	3.002	3.212	3.432
$\frac{3}{16}$	1.442	1.668	1.891	2.096	2.324	2.552	2.781	2.964	3.188	3.412	3.636
$\frac{1}{4}$	1.522	1.761	1.997	2.215	2.456	2.698	2.940	3.136	3.373	3.611	3.848
$\frac{5}{16}$	1.601	1.854	2.103	2.335	2.589	2.844	3.099	3.309	3.559	3.810	4.061
$\frac{3}{8}$	1.681	1.947	2.210	2.454	2.722	2.990	3.259	3.482	3.745	4.009	4.273
$\frac{7}{16}$	1.761	2.040	2.316	2.574	2.855	3.136	3.418	3.654	3.931	4.209	4.486
$\frac{1}{2}$	1.841	2.133	2.422	2.693	2.988	3.282	3.577	3.827	4.117	4.408	4.698
$\frac{9}{16}$	1.920	2.226	2.528	2.813	3.120	3.428	3.737	4.000	4.303	4.607	4.911
$\frac{5}{8}$	2.000	2.319	2.635	2.932	3.253	3.575	3.896	4.172	4.489	4.806	5.123
$\frac{11}{16}$	2.080	2.412	2.741	3.052	3.386	3.721	4.056	4.345	4.675	5.005	5.336
$\frac{3}{4}$	2.159	2.505	2.847	3.171	3.519	3.867	4.215	4.518	4.861	5.205	5.548
$\frac{13}{16}$	2.239	2.598	2.953	3.291	3.652	4.013	4.374	4.690	5.047	5.404	5.761
$\frac{7}{8}$	2.319	2.691	3.060	3.410	3.784	4.159	4.534	4.863	5.233	5.603	5.973
$\frac{15}{16}$	2.398	2.784	3.166	3.530	3.917	4.305	4.693	5.036	5.419	5.802	6.186
2	2.478	2.877	3.272	3.649	4.050	4.451	4.852	5.208	5.605	6.002	6.398
$\frac{1}{16}$	2.558	2.970	3.378	3.769	4.183	4.597	5.012	5.381	5.791	6.201	6.611
$\frac{1}{8}$	2.637	3.063	3.485	3.888	4.316	4.743	5.171	5.554	5.977	6.400	6.823
$\frac{3}{16}$	2.717	3.156	3.591	4.008	4.449	4.889	5.331	5.726	6.163	6.599	7.036

To obtain Face Measure for any thickness, subtract from Over-all Measure the Increment given in table below for corresponding thickness.

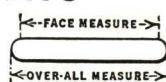
THICKNESS, INCHES										
$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
INCREMENT, INCHES										
$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$

No. 13 — $\frac{5}{16}$
 $2\frac{1}{4}$ — 6

WEIGHTS OF ROUND EDGE FLATS



POUNDS PER LINEAR FOOT
 OVER-ALL MEASURE
 (Continued)



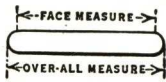
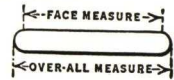
Over-all Measure Inches	THICKNESS, B. W. G. AND INCHES									
	No. 13	No. 12	No. 11	No. 10	No. 9	No. 8	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
$2\frac{1}{4}$	.722	.828	.911	1.016	1.121	1.248	.948	1.416	1.880	2.341
$\frac{5}{8}$	.742	.851	.936	1.044	1.152	1.283	.975	1.456	1.934	2.407
$\frac{3}{8}$	.763	.874	.962	1.073	1.184	1.318	1.001	1.496	1.987	2.473
$\frac{7}{16}$	.783	.897	.987	1.101	1.215	1.354	1.028	1.536	2.040	2.540
$\frac{1}{2}$	.803	.920	1.013	1.130	1.247	1.389	1.054	1.576	2.093	2.606
$\frac{5}{8}$	.843	.967	1.064	1.187	1.310	1.459	1.108	1.655	2.199	2.739
$\frac{3}{4}$	.884	1.013	1.115	1.244	1.373	1.529	1.161	1.735	2.305	2.872
$\frac{7}{8}$	.924	1.059	1.166	1.301	1.435	1.599	1.214	1.815	2.412	3.004
3	.964	1.106	1.217	1.358	1.498	1.669	1.267	1.895	2.518	3.138
$\frac{1}{8}$	.....	.....	.....	1.415	1.561	1.739	1.320	1.974	2.624	3.270
$\frac{1}{4}$	.....	.....	.....	1.472	1.624	1.809	1.373	2.054	2.730	3.403
$\frac{3}{8}$	.....	.....	.....	1.528	1.687	1.879	1.426	2.134	2.837	3.536
$\frac{1}{2}$	.....	.....	.....	1.585	1.750	1.950	1.479	2.213	2.943	3.669
$\frac{5}{8}$	.....	.....	.....	.....	.....	.....	.....	2.293	3.049	3.802
$\frac{3}{4}$	.....	.....	.....	.....	.....	.....	.....	2.373	3.155	3.934
$\frac{7}{8}$	.....	.....	.....	.....	.....	.....	.....	2.452	3.262	4.067
4	.....	.....	.....	.....	.....	.....	.....	2.532	3.368	4.200
$\frac{1}{8}$	.....	.....	.....	.....	.....	.....	.....	.....	3.474	4.333
$\frac{1}{4}$	.....	.....	.....	.....	.....	.....	.....	.....	3.580	4.466
$\frac{3}{8}$	.....	.....	.....	.....	.....	.....	.....	.....	3.687	4.598
$\frac{1}{2}$	.....	.....	.....	.....	.....	.....	.....	.....	3.793	4.731
$\frac{5}{8}$	.....	.....	.....	.....	.....	.....	.....	.....	3.899	4.864
$\frac{3}{4}$	.....	.....	.....	.....	.....	.....	.....	.....	4.005	4.997
$\frac{7}{8}$	.....	.....	.....	.....	.....	.....	.....	.....	4.112	5.130
5	.....	.....	.....	.....	.....	.....	.....	.....	4.218	5.263
$\frac{1}{8}$	.....	.....	.....	.....	.....	.....	.....	.....	4.324	5.395
$\frac{1}{4}$	.....	.....	.....	.....	.....	.....	.....	.....	4.430	5.528
$\frac{3}{8}$	.....	.....	.....	.....	.....	.....	.....	.....	4.537	5.661
$\frac{1}{2}$	.....	.....	.....	.....	.....	.....	.....	.....	4.643	5.794
$\frac{5}{8}$	.....	.....	.....	.....	.....	.....	.....	.....	4.749	5.927
$\frac{3}{4}$	.....	.....	.....	.....	.....	.....	.....	.....	4.855	6.059
$\frac{7}{8}$	.....	.....	.....	.....	.....	.....	.....	.....	4.962	6.192
6	.....	.....	.....	.....	.....	.....	.....	.....	5.068	6.325

To obtain Face Measure for any thickness, subtract from Over-all Measure the Increment given in table below for corresponding thickness.

THICKNESS, B. W. G. AND INCHES									
No. 13	No. 12	No. 11	No. 10	No. 9	No. 8	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
INCREMENT, INCHES									
.0475	.0545	.0600	.0670	.0740	.0825	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$

$\frac{3}{8}$ —1
 $2\frac{1}{4}$ —6

WEIGHTS OF ROUND EDGE FLATS


 POUNDS PER LINEAR FOOT
 OVER-ALL MEASURE
 (Concluded)


Over-all Measure Inches	THICKNESS, INCHES										
	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
$2\frac{1}{4}$	2.797	3.249	3.697	4.128	4.581	5.035	5.490	5.899	6.348	6.798	7.248
$\frac{5}{16}$	2.876	3.342	3.803	4.247	4.714	5.182	5.649	6.072	6.534	6.998	7.461
$\frac{3}{8}$	2.956	3.435	3.910	4.367	4.847	5.328	5.809	6.244	6.720	7.197	7.673
$\frac{7}{16}$	3.036	3.528	4.016	4.486	4.980	5.474	5.968	6.417	6.906	7.396	7.886
$\frac{1}{2}$	3.116	3.621	4.122	4.606	5.113	5.620	6.127	6.590	7.092	7.595	8.098
$\frac{5}{8}$	3.275	3.807	4.335	4.845	5.378	5.912	6.446	6.935	7.464	7.994	8.523
$\frac{3}{4}$	3.434	3.993	4.547	5.084	5.644	6.204	6.765	7.280	7.836	8.392	8.948
$\frac{7}{8}$	3.594	4.179	4.760	5.323	5.909	6.496	7.084	7.625	8.208	8.791	9.373
3	3.753	4.365	4.972	5.562	6.175	6.789	7.402	7.971	8.580	9.189	9.798
$\frac{1}{8}$	3.912	4.551	5.185	5.801	6.441	7.081	7.721	8.316	8.952	9.587	10.223
$\frac{1}{4}$	4.072	4.736	5.397	6.040	6.706	7.373	8.040	8.661	9.323	9.986	10.648
$\frac{3}{8}$	4.231	4.922	5.610	6.279	6.972	7.665	8.359	9.007	9.695	10.384	11.073
$\frac{1}{2}$	4.391	5.108	5.822	6.518	7.238	7.957	8.677	9.352	10.067	10.783	11.498
$\frac{5}{8}$	4.550	5.294	6.035	6.757	7.503	8.250	8.996	9.697	10.439	11.181	11.923
$\frac{3}{4}$	4.709	5.480	6.247	6.996	7.769	8.542	9.315	10.043	10.811	11.580	12.348
$\frac{7}{8}$	4.869	5.666	6.460	7.235	8.034	8.834	9.634	10.388	11.183	11.978	12.773
4	5.028	5.852	6.672	7.474	8.300	9.126	9.952	10.733	11.555	12.377	13.198
$\frac{1}{8}$	5.187	6.038	6.885	7.713	8.566	9.418	10.271	11.079	11.927	12.775	13.623
$\frac{1}{4}$	5.347	6.224	7.097	7.953	8.831	9.710	10.590	11.424	12.298	13.173	14.048
$\frac{3}{8}$	5.506	6.410	7.310	8.192	9.097	10.003	10.909	11.769	12.670	13.572	14.473
$\frac{1}{2}$	5.666	6.596	7.522	8.431	9.363	10.295	11.227	12.115	13.042	13.970	14.898
$\frac{5}{8}$	5.825	6.782	7.735	8.670	9.628	10.587	11.546	12.460	13.414	14.369	15.323
$\frac{3}{4}$	5.984	6.968	7.947	8.909	9.894	10.879	11.865	12.805	13.786	14.767	15.748
$\frac{7}{8}$	6.144	7.154	8.160	9.148	10.159	11.171	12.184	13.150	14.158	15.166	16.173
5	6.303	7.340	8.372	9.387	10.425	11.464	12.502	13.496	14.530	15.564	16.598
$\frac{1}{8}$	6.462	7.525	8.585	9.626	10.691	11.756	12.821	13.841	14.902	15.962	17.023
$\frac{1}{4}$	6.622	7.711	8.797	9.865	10.956	12.048	13.140	14.186	15.273	16.361	17.448
$\frac{3}{8}$	6.781	7.897	9.010	10.104	11.222	12.340	13.459	14.532	15.645	16.759	17.873
$\frac{1}{2}$	6.941	8.083	9.222	10.343	11.488	12.632	13.777	14.877	16.017	17.158	18.298
$\frac{5}{8}$	7.100	8.269	9.435	10.582	11.753	12.925	14.096	15.222	16.389	17.556	18.723
$\frac{3}{4}$	7.259	8.455	9.647	10.821	12.019	13.217	14.415	15.568	16.761	17.955	19.148
$\frac{7}{8}$	7.419	8.641	9.860	11.060	12.284	13.509	14.734	15.913	17.133	18.353	19.573
6	7.578	8.827	10.072	11.299	12.550	13.801	15.052	16.258	17.505	18.752	19.998

To obtain Face Measure for any thickness, subtract from Over-all Measure the Increment given in table below for corresponding thickness.

THICKNESS, INCHES										
$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
INCREMENT, INCHES										
$\frac{3}{16}$	$\frac{1}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{15}{8}$

WEIGHTS OF FLAT ROLLED STRIP STEEL

POUNDS PER LINEAR FOOT

Thickness by Birmingham or Stubs Iron Wire Gage

For widths from $\frac{1}{4}$ inch to $\frac{3}{4}$ inch and thicknesses from No. 19 to No. 11 B.W.G.

Width Inches	No. 19 .042 In.	No. 18 .049 In.	No. 17 .058 In.	No. 16 .065 In.	No. 15 .072 In.	No. 14 .083 In.	No. 13 .095 In.	No. 12 .109 In.	No. 11 .120 In.
$\frac{1}{4}$	.036	.042	.049	.055	.061	.071	.081	.093	.102
$\frac{17}{64}$	.038	.044	.052	.059	.065	.075	.086	.098	.108
$\frac{9}{32}$	.040	.047	.055	.062	.069	.079	.091	.104	.115
$\frac{19}{64}$	.042	.049	.059	.066	.073	.084	.096	.110	.121
$\frac{5}{16}$	.045	.052	.062	.069	.077	.088	.101	.116	.128
$\frac{21}{64}$	.047	.055	.065	.073	.080	.093	.106	.122	.134
$\frac{11}{32}$	.049	.057	.068	.076	.084	.097	.111	.127	.140
$\frac{23}{64}$	.051	.060	.071	.079	.088	.101	.116	.133	.147
$\frac{3}{8}$	.054	.062	.074	.083	.092	.106	.121	.139	.153
$\frac{25}{64}$	.056	.065	.077	.086	.096	.110	.126	.145	.159
$\frac{13}{32}$	.058	.068	.080	.090	.099	.115	.131	.151	.166
$\frac{27}{64}$	.060	.070	.083	.093	.103	.119	.136	.156	.172
$\frac{7}{16}$	.062	.073	.086	.097	.107	.123	.141	.162	.179
$\frac{29}{64}$	.065	.075	.089	.100	.111	.128	.146	.168	.185
$\frac{15}{32}$	.067	.078	.092	.104	.115	.132	.151	.174	.191
$\frac{31}{64}$	.069	.081	.096	.107	.119	.137	.156	.180	.198
$\frac{1}{2}$	.071	.083	.099	.111	.122	.141	.162	.185	.204
$\frac{33}{64}$	.074	.086	.102	.114	.126	.146	.167	.191	.210
$\frac{17}{32}$	.076	.089	.105	.117	.130	.150	.172	.197	.217
$\frac{35}{64}$	.078	.091	.108	.121	.134	.154	.177	.203	.223
$\frac{9}{16}$	.080	.094	.111	.124	.138	.159	.182	.208	.230
$\frac{37}{64}$	.083	.096	.114	.128	.142	.163	.187	.214	.236
$\frac{19}{32}$	.085	.099	.117	.131	.145	.168	.192	.220	.242
$\frac{39}{64}$	.087	.102	.120	.135	.149	.172	.197	.226	.249
$\frac{5}{8}$	.089	.104	.123	.138	.153	.176	.202	.232	.255
$\frac{41}{64}$	.091	.107	.126	.142	.157	.181	.207	.237	.261
$\frac{21}{32}$	.094	.109	.129	.145	.161	.185	.212	.243	.268
$\frac{43}{64}$	.096	.112	.132	.148	.164	.190	.217	.249	.274
$\frac{11}{16}$	.098	.115	.136	.152	.168	.194	.222	.255	.281
$\frac{45}{64}$	.100	.117	.139	.155	.172	.198	.227	.261	.287
$\frac{23}{32}$	.103	.120	.142	.159	.176	.203	.232	.266	.293
$\frac{47}{64}$	.105	.122	.145	.162	.180	.207	.237	.272	.300
$\frac{3}{4}$	.107	.125	.148	.166	.184	.212	.242	.278	.306

WEIGHTS OF HALF-OVAL STEEL BARS

Size Inches	Weight of one foot, Pounds	No. of feet in a bundle of 112 lbs.	Size, Inches	Weight of one foot, Pounds	No. of feet in a bundle of 112 lbs.
$\frac{3}{8} \times \frac{3}{32}$	.10	1120	$1\frac{1}{4} \times \frac{1}{4}$	.80	140
$\frac{3}{8} \times \frac{1}{8}$	.128	875	$1\frac{1}{4} \times \frac{5}{16}$	1.00	112
$\frac{1}{2} \times \frac{3}{32}$	.125	896	$1\frac{1}{4} \times \frac{3}{8}$	1.25	89
$\frac{1}{2} \times \frac{1}{8}$	.165	678	$1\frac{3}{8} \times \frac{1}{4}$	.88	127
$\frac{1}{2} \times \frac{5}{32}$	.180	622	$1\frac{3}{8} \times \frac{5}{16}$	1.12	100
$\frac{1}{2} \times \frac{3}{16}$	.256	437	$1\frac{3}{8} \times \frac{3}{8}$	1.45	77
$\frac{5}{8} \times \frac{1}{8}$	.210	533	$1\frac{1}{2} \times \frac{1}{4}$	1.00	112
$\frac{5}{8} \times \frac{5}{32}$	.260	430	$1\frac{1}{2} \times \frac{5}{16}$	1.28	87
$\frac{5}{8} \times \frac{3}{16}$	.336	333	$1\frac{1}{2} \times \frac{3}{8}$	1.50	74
$\frac{5}{8} \times \frac{1}{4}$	.410	273	$1\frac{1}{2} \times \frac{7}{16}$	1.75	64
$\frac{3}{4} \times \frac{1}{8}$	.272	411	$1\frac{1}{2} \times \frac{1}{2}$	2.00	56
$\frac{3}{4} \times \frac{5}{32}$	.310	361	$1\frac{3}{4} \times \frac{3}{8}$	1.75	64
$\frac{3}{4} \times \frac{3}{16}$	.384	292	$1\frac{3}{4} \times \frac{1}{2}$	2.05	54
$\frac{3}{4} \times \frac{1}{4}$	.500	224	$1\frac{3}{4} \times \frac{1}{2}$	2.30	48
$\frac{3}{4} \times \frac{5}{16}$	.620	180	$2 \times \frac{3}{8}$	1.80	62
$\frac{7}{8} \times \frac{1}{8}$	.320	350	$2 \times \frac{7}{16}$	2.30	49
$\frac{7}{8} \times \frac{5}{32}$	.380	295	$2 \times \frac{1}{2}$	2.60	43
$\frac{7}{8} \times \frac{3}{16}$	.430	260	$2\frac{1}{2} \times \frac{3}{8}$	2.40	
$\frac{7}{8} \times \frac{1}{4}$	.580	193	$2\frac{1}{2} \times \frac{1}{2}$	3.15	
$\frac{7}{8} \times \frac{5}{16}$	.724	154	$2\frac{1}{2} \times \frac{5}{8}$	4.10	
$\frac{7}{8} \times \frac{3}{8}$	.900	124	$2\frac{1}{2} \times \frac{3}{4}$	5.00	
$1 \times \frac{1}{8}$	.370	302	$3 \times \frac{3}{8}$	3.00	
$1 \times \frac{3}{16}$	.500	224	$3 \times \frac{1}{2}$	4.00	
$1 \times \frac{1}{4}$	.650	172	$3 \times \frac{5}{8}$	5.00	
$1 \times \frac{5}{16}$	.830	135	$3 \times \frac{3}{4}$	6.00	
$1 \times \frac{3}{8}$	1.00	112			
$1\frac{1}{8} \times \frac{1}{4}$	.75	149			
$1\frac{1}{8} \times \frac{5}{16}$	.92	122			
$1\frac{1}{8} \times \frac{3}{8}$	1.10	102			

PIPE

DIMENSIONS							COUPLINGS			PROPERTIES		
Nom. Dia. In.	Outside Dia. In.	Inside Dia. In.	Thick-ness In.	Wt. per Ft., Lb.		Thread per Inch	Outside Dia. In.	Length In.	Weight Lb.	I In. ⁴	A In. ²	r In.
STANDARD												
1/8	.405	.269	.068	.24	.25	27	.562	7/8	.03	.001	.072	.12
1/4	.540	.364	.088	.42	.43	18	.685	1	.04	.003	.125	.16
3/8	.675	.493	.091	.57	.57	18	.848	1 1/8	.07	.007	.167	.21
1/2	.840	.622	.109	.85	.85	14	1.024	1 3/8	.12	.017	.250	.26
3/4	1.050	.824	.113	1.13	1.13	14	1.281	1 5/8	.21	.037	.333	.33
1	1.315	1.049	.133	1.68	1.68	11 1/2	1.576	1 7/8	.35	.087	.494	.42
1 1/4	1.660	1.380	.140	2.27	2.28	11 1/2	1.950	2 1/8	.55	.195	.669	.54
1 1/2	1.900	1.610	.145	2.72	2.73	11 1/2	2.218	2 3/8	.76	.310	.799	.62
2	2.375	2.067	.154	3.65	3.68	11 1/2	2.760	2 5/8	1.23	.666	1.075	.79
2 1/2	2.875	2.469	.203	5.79	5.82	8	3.276	2 7/8	1.76	1.530	1.704	.95
3	3.500	3.068	.216	7.58	7.62	8	3.948	3 1/8	2.55	3.017	2.228	1.16
3 1/2	4.000	3.548	.226	9.11	9.20	8	4.591	3 5/8	4.33	4.788	2.680	1.34
4	4.500	4.026	.237	10.79	10.89	8	5.091	3 5/8	5.41	7.233	3.174	1.51
5	5.563	5.047	.258	14.62	14.81	8	6.296	4 1/8	9.16	15.16	4.300	1.88
6	6.625	6.065	.280	18.97	19.19	8	7.358	4 1/8	10.82	28.14	5.581	2.25
8	8.625	8.071	.277	24.70	25.00	8	9.420	4 5/8	15.84	63.35	7.265	2.95
8	8.625	7.981	.322	28.55	28.81	8	9.420	4 5/8	15.84	72.49	8.399	2.94
10	10.750	10.192	.279	31.20	32.00	8	11.721	6 1/8	33.92	125.4	9.178	3.70
10	10.750	10.136	.307	34.24	35.00	8	11.721	6 1/8	33.92	137.4	10.07	3.69
10	10.750	10.020	.365	40.48	41.13	8	11.721	6 1/8	33.92	160.7	11.91	3.67
12	12.750	12.090	.330	43.77	45.00	8	13.958	6 1/8	48.27	248.5	12.88	4.39
12	12.750	12.000	.375	49.56	50.71	8	13.958	6 1/8	48.27	279.3	14.38	4.38
EXTRA STRONG												
1/8	.405	.215	.095	.31	.32	27	.582	1 1/8	.05	.001	.093	.12
1/4	.540	.302	.119	.54	.54	18	.724	1 3/8	.07	.004	.157	.16
3/8	.675	.423	.126	.74	.75	18	.898	1 5/8	.13	.009	.217	.20
1/2	.840	.546	.147	1.09	1.10	14	1.085	1 7/8	.22	.020	.320	.25
3/4	1.050	.742	.154	1.47	1.49	14	1.316	2 1/8	.33	.045	.433	.32
1	1.315	.957	.179	2.17	2.20	11 1/2	1.575	2 3/8	.47	.106	.639	.41
1 1/4	1.660	1.278	.191	3.00	3.05	11 1/2	2.054	2 7/8	1.04	.242	.881	.52
1 1/2	1.900	1.500	.200	3.63	3.69	11 1/2	2.294	2 7/8	1.17	.391	1.068	.61
2	2.375	1.939	.218	5.02	5.13	11 1/2	2.870	3 5/8	2.17	.868	1.477	.77
2 1/2	2.875	2.323	.276	7.66	7.83	8	3.389	4 1/8	3.43	1.924	2.254	.92
3	3.500	2.900	.300	10.25	10.46	8	4.014	4 1/8	4.13	3.894	3.016	1.14
3 1/2	4.000	3.364	.318	12.51	12.82	8	4.628	4 5/8	6.29	6.280	3.678	1.31
4	4.500	3.826	.337	14.98	15.39	8	5.233	4 5/8	8.16	9.610	4.407	1.48
5	5.563	4.813	.375	20.78	21.42	8	6.420	5 1/8	12.87	20.67	6.112	1.84
6	6.625	5.761	.432	28.57	29.33	8	7.482	5 1/8	15.18	40.49	8.405	2.20
8	8.625	7.625	.500	43.39	44.72	8	9.596	6 1/8	26.63	105.7	12.76	2.88
10	10.750	9.750	.500	54.74	56.94	8	11.958	6 5/8	44.16	211.9	16.10	3.63
12	12.750	11.750	.500	65.42	68.02	8	13.958	6 5/8	51.99	361.5	19.24	4.34
DOUBLE-EXTRA STRONG												
1/2	.840	.252	.294	1.71	1.73	14	1.085	1 7/8	.22	.024	.504	.22
3/4	1.050	.434	.308	2.44	2.46	14	1.316	2 1/8	.33	.058	.718	.28
1	1.315	.599	.358	3.66	3.68	11 1/2	1.575	2 3/8	.47	.140	1.076	.36
1 1/4	1.660	.896	.382	5.21	5.27	11 1/2	2.054	2 7/8	1.04	.341	1.534	.47
1 1/2	1.900	1.100	.400	6.41	6.47	11 1/2	2.294	2 7/8	1.17	.568	1.885	.55
2	2.375	1.503	.436	9.03	9.14	11 1/2	2.870	3 5/8	2.17	1.311	2.656	.70
2 1/2	2.875	1.771	.552	13.70	13.87	8	3.389	4 1/8	3.43	2.871	4.028	.84
3	3.500	2.300	.600	18.58	18.79	8	4.014	4 1/8	4.13	5.992	5.466	1.05
3 1/2	4.000	2.728	.636	22.85	23.16	8	4.628	4 5/8	6.29	9.848	6.721	1.21
4	4.500	3.152	.674	27.54	27.95	8	5.233	4 5/8	8.16	15.28	8.101	1.37
5	5.563	4.063	.750	38.55	39.20	8	6.420	5 1/8	12.87	33.64	11.34	1.72
6	6.625	4.897	.864	53.16	53.92	8	7.482	5 1/8	15.18	66.33	15.64	2.06
8	8.625	6.875	.875	72.42	73.76	8	9.596	6 3/8	26.63	162.0	21.30	2.76

Pipe 14" and larger is sold by actual O. S. diameter and thickness.

Sizes 14", 15", and 16" are available regularly in thicknesses varying by 1/16" from 1/4" to 1", inclusive.

$\frac{1}{16}$ TO
 $19\frac{7}{8}$

AREAS AND CIRCUMFERENCES OF CIRCLES

Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference
$\frac{1}{16}$	.0031	.1963	5	19.6350	15.7080	10	78.540	31.4160	15	176.715	47.1240
$\frac{1}{8}$	.0123	.3927	$\frac{1}{8}$	20.6290	16.1007	$\frac{1}{8}$	80.516	31.8087	$\frac{1}{8}$	179.673	47.5167
$\frac{1}{4}$	.0491	.7854	$\frac{1}{4}$	21.6476	16.4934	$\frac{1}{4}$	82.516	32.2014	$\frac{1}{4}$	182.655	47.9094
$\frac{3}{8}$	.1104	1.1781	$\frac{3}{8}$	22.6907	16.8861	$\frac{3}{8}$	84.541	32.5941	$\frac{3}{8}$	185.661	48.3021
$\frac{1}{2}$	.1963	1.5708	$\frac{1}{2}$	23.7583	17.2788	$\frac{1}{2}$	86.590	32.9868	$\frac{1}{2}$	188.692	48.6948
$\frac{5}{8}$	.3068	1.9635	$\frac{5}{8}$	24.8505	17.6715	$\frac{5}{8}$	88.664	33.3795	$\frac{5}{8}$	191.748	49.0875
$\frac{3}{4}$	.4418	2.3562	$\frac{3}{4}$	25.9673	18.0642	$\frac{3}{4}$	90.763	33.7722	$\frac{3}{4}$	194.828	49.4802
$\frac{7}{8}$	.6013	2.7489	$\frac{7}{8}$	27.1086	18.4569	$\frac{7}{8}$	92.886	34.1649	$\frac{7}{8}$	197.933	49.8729
1	.7854	3.1416	6	28.2744	18.8496	11	95.033	34.5576	16	201.062	50.2656
$\frac{1}{8}$	.9940	3.5343	$\frac{1}{8}$	29.4648	19.2423	$\frac{1}{8}$	97.205	34.9503	$\frac{1}{8}$	204.216	50.6583
$\frac{1}{4}$	1.2272	3.9270	$\frac{1}{4}$	30.6797	19.6350	$\frac{1}{4}$	99.402	35.3430	$\frac{1}{4}$	207.395	51.0510
$\frac{3}{8}$	1.4849	4.3197	$\frac{3}{8}$	31.9191	20.0277	$\frac{3}{8}$	101.623	35.7357	$\frac{3}{8}$	210.598	51.4437
$\frac{1}{2}$	1.7671	4.7124	$\frac{1}{2}$	33.1831	20.4204	$\frac{1}{2}$	103.869	36.1284	$\frac{1}{2}$	213.825	51.8364
$\frac{5}{8}$	2.0739	5.1051	$\frac{5}{8}$	34.4717	20.8131	$\frac{5}{8}$	106.139	36.5211	$\frac{5}{8}$	217.077	52.2291
$\frac{3}{4}$	2.4053	5.4978	$\frac{3}{4}$	35.7848	21.2058	$\frac{3}{4}$	108.434	36.9138	$\frac{3}{4}$	220.354	52.6218
$\frac{7}{8}$	2.7612	5.8905	$\frac{7}{8}$	37.1224	21.5985	$\frac{7}{8}$	110.754	37.3065	$\frac{7}{8}$	223.655	53.0145
2	3.1416	6.2832	7	38.4846	21.9912	12	113.098	37.6992	17	226.981	53.4072
$\frac{1}{8}$	3.5466	6.6759	$\frac{1}{8}$	39.8713	22.3839	$\frac{1}{8}$	115.466	38.0919	$\frac{1}{8}$	230.331	53.7999
$\frac{1}{4}$	3.9761	7.0686	$\frac{1}{4}$	41.2826	22.7766	$\frac{1}{4}$	117.859	38.4846	$\frac{1}{4}$	233.706	54.1926
$\frac{3}{8}$	4.4301	7.4613	$\frac{3}{8}$	42.7184	23.1693	$\frac{3}{8}$	120.277	38.8773	$\frac{3}{8}$	237.105	54.5853
$\frac{1}{2}$	4.9087	7.8540	$\frac{1}{2}$	44.1787	23.5620	$\frac{1}{2}$	122.719	39.2700	$\frac{1}{2}$	240.529	54.9780
$\frac{5}{8}$	5.4119	8.2467	$\frac{5}{8}$	45.6636	23.9547	$\frac{5}{8}$	125.185	39.6627	$\frac{5}{8}$	243.977	55.3707
$\frac{3}{4}$	5.9396	8.6394	$\frac{3}{4}$	47.1731	24.3474	$\frac{3}{4}$	127.677	40.0554	$\frac{3}{4}$	247.450	55.7634
$\frac{7}{8}$	6.4918	9.0321	$\frac{7}{8}$	48.7071	24.7401	$\frac{7}{8}$	130.192	40.4481	$\frac{7}{8}$	250.948	56.1561
3	7.0686	9.4248	8	50.2656	25.1328	13	132.733	40.8408	18	254.470	56.5488
$\frac{1}{8}$	7.6699	9.8175	$\frac{1}{8}$	51.8487	25.5255	$\frac{1}{8}$	135.297	41.2335	$\frac{1}{8}$	258.016	56.9415
$\frac{1}{4}$	8.2958	10.2102	$\frac{1}{4}$	53.4563	25.9182	$\frac{1}{4}$	137.887	41.6262	$\frac{1}{4}$	261.587	57.3342
$\frac{3}{8}$	8.9462	10.6029	$\frac{3}{8}$	55.0884	26.3109	$\frac{3}{8}$	140.501	42.0189	$\frac{3}{8}$	265.183	57.7269
$\frac{1}{2}$	9.6211	10.9956	$\frac{1}{2}$	56.7451	26.7036	$\frac{1}{2}$	143.139	42.4116	$\frac{1}{2}$	268.803	58.1196
$\frac{5}{8}$	10.3206	11.3883	$\frac{5}{8}$	58.4264	27.0963	$\frac{5}{8}$	145.802	42.8043	$\frac{5}{8}$	272.448	58.5123
$\frac{3}{4}$	11.0447	11.7810	$\frac{3}{4}$	60.1322	27.4890	$\frac{3}{4}$	148.490	43.1970	$\frac{3}{4}$	276.117	58.9050
$\frac{7}{8}$	11.7933	12.1737	$\frac{7}{8}$	61.8625	27.8817	$\frac{7}{8}$	151.202	43.5897	$\frac{7}{8}$	279.811	59.2977
4	12.5664	12.5664	9	63.6174	28.2744	14	153.938	43.9824	19	283.529	59.6904
$\frac{1}{8}$	13.3641	12.9591	$\frac{1}{8}$	65.3968	28.6671	$\frac{1}{8}$	156.700	44.3751	$\frac{1}{8}$	287.272	60.0831
$\frac{1}{4}$	14.1863	13.3518	$\frac{1}{4}$	67.2008	29.0598	$\frac{1}{4}$	159.485	44.7678	$\frac{1}{4}$	291.040	60.4758
$\frac{3}{8}$	15.0330	13.7445	$\frac{3}{8}$	69.0293	29.4525	$\frac{3}{8}$	162.296	45.1605	$\frac{3}{8}$	294.832	60.8685
$\frac{1}{2}$	15.9043	14.1372	$\frac{1}{2}$	70.8823	29.8452	$\frac{1}{2}$	165.130	45.5532	$\frac{1}{2}$	298.648	61.2612
$\frac{5}{8}$	16.8002	14.5299	$\frac{5}{8}$	72.7599	30.2379	$\frac{5}{8}$	167.990	45.9459	$\frac{5}{8}$	302.489	61.6539
$\frac{3}{4}$	17.7206	14.9226	$\frac{3}{4}$	74.6621	30.6306	$\frac{3}{4}$	170.874	46.3386	$\frac{3}{4}$	306.355	62.0466
$\frac{7}{8}$	18.6655	15.3153	$\frac{7}{8}$	76.5889	31.0233	$\frac{7}{8}$	173.782	46.7313	$\frac{7}{8}$	310.245	62.4393

AREAS AND CIRCUMFERENCES OF CIRCLES

20 To
39 $\frac{7}{8}$

Diam-eter	Area	Circum-ference	Diam-eter	Area	Circum-ference	Diam-eter	Area	Circum-ference	Diam-eter	Area	Circum-ference
20	314.160	62.8320	25	490.875	78.5400	30	706.860	94.248	35	962.115	109.956
$\frac{1}{8}$	318.099	63.2247	$\frac{1}{8}$	495.796	78.9327	$\frac{1}{8}$	712.763	94.641	$\frac{1}{8}$	969.000	110.349
$\frac{1}{4}$	322.063	63.6174	$\frac{1}{4}$	500.742	79.3254	$\frac{1}{4}$	718.690	95.033	$\frac{1}{4}$	975.909	110.741
$\frac{3}{8}$	326.051	64.0101	$\frac{3}{8}$	505.712	79.7181	$\frac{3}{8}$	724.642	95.426	$\frac{3}{8}$	982.842	111.134
$\frac{1}{2}$	330.064	64.4028	$\frac{1}{2}$	510.706	80.1108	$\frac{1}{2}$	730.618	95.819	$\frac{1}{2}$	989.800	111.527
$\frac{5}{8}$	334.102	64.7955	$\frac{5}{8}$	515.726	80.5035	$\frac{5}{8}$	736.619	96.212	$\frac{5}{8}$	996.783	111.919
$\frac{3}{4}$	338.164	65.1828	$\frac{3}{4}$	520.769	80.8962	$\frac{3}{4}$	742.645	96.604	$\frac{3}{4}$	1003.790	112.312
$\frac{7}{8}$	342.250	65.5809	$\frac{7}{8}$	525.838	81.2889	$\frac{7}{8}$	748.695	96.997	$\frac{7}{8}$	1010.822	112.705
21	346.361	65.9736	26	530.930	81.6816	31	754.769	97.390	36	1017.878	113.098
$\frac{1}{8}$	350.497	66.3663	$\frac{1}{8}$	536.048	82.0743	$\frac{1}{8}$	760.869	97.782	$\frac{1}{8}$	1024.960	113.490
$\frac{1}{4}$	354.657	66.7590	$\frac{1}{4}$	541.190	82.4670	$\frac{1}{4}$	766.992	98.175	$\frac{1}{4}$	1032.065	113.883
$\frac{3}{8}$	358.842	67.1517	$\frac{3}{8}$	546.356	82.8597	$\frac{3}{8}$	773.140	98.568	$\frac{3}{8}$	1039.195	114.276
$\frac{1}{2}$	363.051	67.5444	$\frac{1}{2}$	551.547	83.2524	$\frac{1}{2}$	779.313	98.960	$\frac{1}{2}$	1046.349	114.668
$\frac{5}{8}$	367.285	67.9371	$\frac{5}{8}$	556.763	83.6451	$\frac{5}{8}$	785.510	99.353	$\frac{5}{8}$	1053.528	115.061
$\frac{3}{4}$	371.543	68.3298	$\frac{3}{4}$	562.003	84.0378	$\frac{3}{4}$	791.732	99.746	$\frac{3}{4}$	1060.732	115.454
$\frac{7}{8}$	375.826	68.7225	$\frac{7}{8}$	567.267	84.4305	$\frac{7}{8}$	797.979	100.138	$\frac{7}{8}$	1067.960	115.846
22	380.134	69.1152	27	572.557	84.8232	32	804.250	100.531	37	1075.213	116.239
$\frac{1}{8}$	384.466	69.5079	$\frac{1}{8}$	577.870	85.2159	$\frac{1}{8}$	810.545	100.924	$\frac{1}{8}$	1082.490	116.632
$\frac{1}{4}$	388.822	69.9006	$\frac{1}{4}$	583.209	85.6086	$\frac{1}{4}$	816.865	101.317	$\frac{1}{4}$	1089.792	117.025
$\frac{3}{8}$	393.203	70.2933	$\frac{3}{8}$	588.571	86.0013	$\frac{3}{8}$	823.210	101.709	$\frac{3}{8}$	1097.118	117.417
$\frac{1}{2}$	397.609	70.6860	$\frac{1}{2}$	593.959	86.3940	$\frac{1}{2}$	829.579	102.102	$\frac{1}{2}$	1104.469	117.810
$\frac{5}{8}$	402.038	71.0787	$\frac{5}{8}$	599.371	86.7867	$\frac{5}{8}$	835.972	102.495	$\frac{5}{8}$	1111.844	118.203
$\frac{3}{4}$	406.494	71.4714	$\frac{3}{4}$	604.807	87.1794	$\frac{3}{4}$	842.391	102.887	$\frac{3}{4}$	1119.244	118.595
$\frac{7}{8}$	410.973	71.8641	$\frac{7}{8}$	610.268	87.5721	$\frac{7}{8}$	848.833	103.280	$\frac{7}{8}$	1126.669	118.988
23	415.477	72.2568	28	615.754	87.9648	33	855.301	103.673	38	1134.118	119.381
$\frac{1}{8}$	420.004	72.6495	$\frac{1}{8}$	621.264	88.3575	$\frac{1}{8}$	861.792	104.065	$\frac{1}{8}$	1141.591	119.773
$\frac{1}{4}$	424.558	73.0422	$\frac{1}{4}$	626.798	88.7502	$\frac{1}{4}$	868.309	104.458	$\frac{1}{4}$	1149.089	120.166
$\frac{3}{8}$	429.135	73.4349	$\frac{3}{8}$	632.357	89.1429	$\frac{3}{8}$	874.850	104.851	$\frac{3}{8}$	1156.612	120.559
$\frac{1}{2}$	433.737	73.8276	$\frac{1}{2}$	637.941	89.5356	$\frac{1}{2}$	881.415	105.244	$\frac{1}{2}$	1164.159	120.952
$\frac{5}{8}$	438.364	74.2203	$\frac{5}{8}$	643.549	89.9283	$\frac{5}{8}$	888.005	105.636	$\frac{5}{8}$	1171.731	121.344
$\frac{3}{4}$	443.015	74.6130	$\frac{3}{4}$	649.182	90.3210	$\frac{3}{4}$	894.620	106.029	$\frac{3}{4}$	1179.327	121.737
$\frac{7}{8}$	447.690	75.0057	$\frac{7}{8}$	654.840	90.7137	$\frac{7}{8}$	901.259	106.422	$\frac{7}{8}$	1186.948	122.130
24	452.390	75.3984	29	660.521	91.1064	34	907.922	106.814	39	1194.593	122.522
$\frac{1}{8}$	457.115	75.7911	$\frac{1}{8}$	666.228	91.4991	$\frac{1}{8}$	914.611	107.207	$\frac{1}{8}$	1202.263	122.915
$\frac{1}{4}$	461.864	76.1838	$\frac{1}{4}$	671.959	91.8918	$\frac{1}{4}$	921.323	107.600	$\frac{1}{4}$	1209.958	123.308
$\frac{3}{8}$	466.638	76.5765	$\frac{3}{8}$	677.714	92.2845	$\frac{3}{8}$	928.061	107.992	$\frac{3}{8}$	1217.677	123.700
$\frac{1}{2}$	471.436	76.9692	$\frac{1}{2}$	683.494	92.6772	$\frac{1}{2}$	934.822	108.385	$\frac{1}{2}$	1225.420	124.093
$\frac{5}{8}$	476.259	77.3619	$\frac{5}{8}$	689.299	93.0699	$\frac{5}{8}$	941.609	108.778	$\frac{5}{8}$	1233.188	124.486
$\frac{3}{4}$	481.107	77.7546	$\frac{3}{4}$	695.128	93.4626	$\frac{3}{4}$	948.420	109.171	$\frac{3}{4}$	1240.981	124.879
$\frac{7}{8}$	485.979	78.1473	$\frac{7}{8}$	700.982	93.8553	$\frac{7}{8}$	955.255	109.563	$\frac{7}{8}$	1248.798	125.271

40 TO
59 $\frac{7}{8}$ AREAS AND CIRCUMFERENCES OF
CIRCLES

Diam- eter	Area	Circum- ference	Diam- eter	Area	Circum- ference	Diam- eter	Area	Circum- ference	Diam- eter	Area	Circum- ference
40	1256.64	125.664	45	1590.43	141.372	50	1963.50	157.080	55	2375.83	172.788
$\frac{1}{8}$	1264.51	126.057	$\frac{1}{8}$	1599.28	141.765	$\frac{1}{8}$	1973.33	157.473	$\frac{1}{8}$	2386.65	173.181
$\frac{1}{4}$	1272.40	126.449	$\frac{1}{4}$	1608.16	142.157	$\frac{1}{4}$	1983.18	157.865	$\frac{1}{4}$	2397.48	173.573
$\frac{3}{8}$	1280.31	126.842	$\frac{3}{8}$	1617.05	142.550	$\frac{3}{8}$	1993.06	158.258	$\frac{3}{8}$	2408.34	173.966
$\frac{1}{2}$	1288.25	127.235	$\frac{1}{2}$	1625.97	142.943	$\frac{1}{2}$	2002.97	158.651	$\frac{1}{2}$	2419.23	174.359
$\frac{5}{8}$	1296.22	127.627	$\frac{5}{8}$	1634.92	143.335	$\frac{5}{8}$	2012.89	159.043	$\frac{5}{8}$	2430.14	174.751
$\frac{3}{4}$	1304.21	128.020	$\frac{3}{4}$	1643.89	143.728	$\frac{3}{4}$	2022.85	159.436	$\frac{3}{4}$	2441.07	175.144
$\frac{7}{8}$	1312.22	128.413	$\frac{7}{8}$	1652.89	144.121	$\frac{7}{8}$	2032.82	159.829	$\frac{7}{8}$	2452.03	175.537
41	1320.26	128.806	46	1661.91	144.514	51	2042.83	160.222	56	2463.01	175.930
$\frac{1}{8}$	1328.32	129.198	$\frac{1}{8}$	1670.95	144.906	$\frac{1}{8}$	2052.85	160.614	$\frac{1}{8}$	2474.02	176.322
$\frac{1}{4}$	1336.41	129.591	$\frac{1}{4}$	1680.02	145.299	$\frac{1}{4}$	2062.90	161.007	$\frac{1}{4}$	2485.05	176.715
$\frac{3}{8}$	1344.52	129.984	$\frac{3}{8}$	1689.11	145.692	$\frac{3}{8}$	2072.98	161.400	$\frac{3}{8}$	2496.11	177.108
$\frac{1}{2}$	1352.66	130.376	$\frac{1}{2}$	1698.23	146.084	$\frac{1}{2}$	2083.08	161.792	$\frac{1}{2}$	2507.19	177.500
$\frac{5}{8}$	1360.82	130.769	$\frac{5}{8}$	1707.37	146.477	$\frac{5}{8}$	2093.20	162.185	$\frac{5}{8}$	2518.30	177.893
$\frac{3}{4}$	1369.00	131.162	$\frac{3}{4}$	1716.54	146.870	$\frac{3}{4}$	2103.35	162.578	$\frac{3}{4}$	2529.43	178.286
$\frac{7}{8}$	1377.21	131.554	$\frac{7}{8}$	1725.73	147.262	$\frac{7}{8}$	2113.52	162.970	$\frac{7}{8}$	2540.58	178.678
42	1385.45	131.947	47	1734.95	147.655	52	2123.72	163.363	57	2551.76	179.071
$\frac{1}{8}$	1393.70	132.340	$\frac{1}{8}$	1744.19	148.048	$\frac{1}{8}$	2133.94	163.756	$\frac{1}{8}$	2562.97	179.464
$\frac{1}{4}$	1401.99	132.733	$\frac{1}{4}$	1753.45	148.441	$\frac{1}{4}$	2144.19	164.149	$\frac{1}{4}$	2574.20	179.857
$\frac{3}{8}$	1410.30	133.125	$\frac{3}{8}$	1762.74	148.833	$\frac{3}{8}$	2154.46	164.541	$\frac{3}{8}$	2585.45	180.249
$\frac{1}{2}$	1418.63	133.518	$\frac{1}{2}$	1772.06	149.226	$\frac{1}{2}$	2164.76	164.934	$\frac{1}{2}$	2596.73	180.642
$\frac{5}{8}$	1426.99	133.911	$\frac{5}{8}$	1781.40	149.619	$\frac{5}{8}$	2175.08	165.327	$\frac{5}{8}$	2608.03	181.035
$\frac{3}{4}$	1435.37	134.303	$\frac{3}{4}$	1790.76	150.011	$\frac{3}{4}$	2185.42	165.719	$\frac{3}{4}$	2619.36	181.427
$\frac{7}{8}$	1443.77	134.696	$\frac{7}{8}$	1800.15	150.404	$\frac{7}{8}$	2195.79	166.112	$\frac{7}{8}$	2630.71	181.820
43	1452.20	135.089	48	1809.56	150.797	53	2206.19	166.505	58	2642.09	182.213
$\frac{1}{8}$	1460.66	135.481	$\frac{1}{8}$	1819.00	151.189	$\frac{1}{8}$	2216.61	166.897	$\frac{1}{8}$	2653.49	182.605
$\frac{1}{4}$	1469.14	135.874	$\frac{1}{4}$	1828.46	151.582	$\frac{1}{4}$	2227.05	167.290	$\frac{1}{4}$	2664.91	182.998
$\frac{3}{8}$	1477.64	136.267	$\frac{3}{8}$	1837.95	151.975	$\frac{3}{8}$	2237.52	167.683	$\frac{3}{8}$	2676.36	183.391
$\frac{1}{2}$	1486.17	136.660	$\frac{1}{2}$	1847.46	152.368	$\frac{1}{2}$	2248.01	168.076	$\frac{1}{2}$	2687.84	183.784
$\frac{5}{8}$	1494.73	137.052	$\frac{5}{8}$	1856.99	152.760	$\frac{5}{8}$	2258.53	168.468	$\frac{5}{8}$	2699.33	184.176
$\frac{3}{4}$	1503.30	137.445	$\frac{3}{4}$	1866.55	153.153	$\frac{3}{4}$	2269.07	168.861	$\frac{3}{4}$	2710.86	184.569
$\frac{7}{8}$	1511.91	137.838	$\frac{7}{8}$	1876.14	153.546	$\frac{7}{8}$	2279.64	169.254	$\frac{7}{8}$	2722.41	184.962
44	1520.53	138.230	49	1885.75	153.938	54	2290.23	169.646	59	2733.98	185.354
$\frac{1}{8}$	1529.19	138.623	$\frac{1}{8}$	1895.38	154.331	$\frac{1}{8}$	2300.84	170.039	$\frac{1}{8}$	2745.57	185.747
$\frac{1}{4}$	1537.86	139.016	$\frac{1}{4}$	1905.04	154.724	$\frac{1}{4}$	2311.48	170.432	$\frac{1}{4}$	2757.20	186.140
$\frac{3}{8}$	1546.56	139.408	$\frac{3}{8}$	1914.72	155.116	$\frac{3}{8}$	2322.15	170.824	$\frac{3}{8}$	2768.84	186.532
$\frac{1}{2}$	1555.29	139.801	$\frac{1}{2}$	1924.43	155.509	$\frac{1}{2}$	2332.83	171.217	$\frac{1}{2}$	2780.51	186.925
$\frac{5}{8}$	1564.04	140.194	$\frac{5}{8}$	1934.16	155.902	$\frac{5}{8}$	2343.55	171.610	$\frac{5}{8}$	2792.21	187.318
$\frac{3}{4}$	1572.81	140.587	$\frac{3}{4}$	1943.91	156.295	$\frac{3}{4}$	2354.29	172.003	$\frac{3}{4}$	2803.93	187.711
$\frac{7}{8}$	1581.61	140.979	$\frac{7}{8}$	1953.69	156.687	$\frac{7}{8}$	2365.05	172.395	$\frac{7}{8}$	2815.67	188.103

AREAS AND CIRCUMFERENCES OF
CIRCLES

60 TO
79 $\frac{7}{8}$

Diam-eter	Area	Circum-ference	Diam-eter	Area	Circum-ference	Diam-eter	Area	Circum-ference	Diam-eter	Area	Circum-ference
60	2827.44	188.496	65	3318.31	204.204	70	3848.46	219.912	75	4417.87	235.620
$\frac{1}{8}$	2839.23	188.889	$\frac{1}{8}$	3331.09	204.597	$\frac{1}{8}$	3862.22	220.305	$\frac{1}{8}$	4432.61	236.013
$\frac{1}{4}$	2851.05	189.281	$\frac{1}{4}$	3343.89	204.989	$\frac{1}{4}$	3876.00	220.697	$\frac{1}{4}$	4447.38	236.405
$\frac{3}{8}$	2862.89	189.674	$\frac{3}{8}$	3356.71	205.382	$\frac{3}{8}$	3889.80	221.090	$\frac{3}{8}$	4462.16	236.798
$\frac{1}{2}$	2874.76	190.067	$\frac{1}{2}$	3369.56	205.775	$\frac{1}{2}$	3903.63	221.483	$\frac{1}{2}$	4476.98	237.191
$\frac{5}{8}$	2886.65	190.459	$\frac{5}{8}$	3382.44	206.167	$\frac{5}{8}$	3917.49	221.875	$\frac{5}{8}$	4491.81	237.583
$\frac{3}{4}$	2898.57	190.852	$\frac{3}{4}$	3395.33	206.560	$\frac{3}{4}$	3931.37	222.268	$\frac{3}{4}$	4506.67	237.976
$\frac{7}{8}$	2910.51	191.245	$\frac{7}{8}$	3408.26	206.953	$\frac{7}{8}$	3945.27	222.661	$\frac{7}{8}$	4521.56	238.369
61	2922.47	191.638	66	3421.20	207.346	71	3959.20	223.054	76	4536.47	238.762
$\frac{1}{8}$	2934.46	192.030	$\frac{1}{8}$	3434.17	207.738	$\frac{1}{8}$	3973.15	223.446	$\frac{1}{8}$	4551.41	239.154
$\frac{1}{4}$	2946.48	192.423	$\frac{1}{4}$	3447.17	208.131	$\frac{1}{4}$	3987.13	223.839	$\frac{1}{4}$	4566.36	239.547
$\frac{3}{8}$	2958.52	192.816	$\frac{3}{8}$	3460.19	208.524	$\frac{3}{8}$	4001.13	224.232	$\frac{3}{8}$	4581.35	239.940
$\frac{1}{2}$	2970.58	193.208	$\frac{1}{2}$	3473.24	208.916	$\frac{1}{2}$	4015.16	224.624	$\frac{1}{2}$	4596.36	240.332
$\frac{5}{8}$	2982.67	193.601	$\frac{5}{8}$	3486.30	209.309	$\frac{5}{8}$	4029.21	225.017	$\frac{5}{8}$	4611.39	240.725
$\frac{3}{4}$	2994.78	193.994	$\frac{3}{4}$	3499.40	209.702	$\frac{3}{4}$	4043.29	225.410	$\frac{3}{4}$	4626.45	241.118
$\frac{7}{8}$	3006.92	194.386	$\frac{7}{8}$	3512.52	210.094	$\frac{7}{8}$	4057.39	225.802	$\frac{7}{8}$	4641.53	241.510
62	3019.08	194.779	67	3525.66	210.487	72	4071.51	226.195	77	4656.64	241.903
$\frac{1}{8}$	3031.26	195.172	$\frac{1}{8}$	3538.83	210.880	$\frac{1}{8}$	4085.66	226.588	$\frac{1}{8}$	4671.77	242.296
$\frac{1}{4}$	3043.47	195.565	$\frac{1}{4}$	3552.02	211.273	$\frac{1}{4}$	4099.84	226.981	$\frac{1}{4}$	4686.92	242.689
$\frac{3}{8}$	3055.71	195.957	$\frac{3}{8}$	3565.24	211.665	$\frac{3}{8}$	4114.04	227.373	$\frac{3}{8}$	4702.10	243.081
$\frac{1}{2}$	3067.97	196.350	$\frac{1}{2}$	3578.48	212.058	$\frac{1}{2}$	4128.26	227.766	$\frac{1}{2}$	4717.31	243.474
$\frac{5}{8}$	3080.25	196.743	$\frac{5}{8}$	3591.74	212.451	$\frac{5}{8}$	4142.51	228.159	$\frac{5}{8}$	4732.54	243.867
$\frac{3}{4}$	3092.56	197.135	$\frac{3}{4}$	3605.04	212.843	$\frac{3}{4}$	4156.78	228.551	$\frac{3}{4}$	4747.79	244.259
$\frac{7}{8}$	3104.89	197.528	$\frac{7}{8}$	3618.35	213.236	$\frac{7}{8}$	4171.08	228.944	$\frac{7}{8}$	4763.07	244.652
63	3117.25	197.921	68	3631.69	213.629	73	4185.40	229.337	78	4778.37	245.045
$\frac{1}{8}$	3129.64	198.313	$\frac{1}{8}$	3645.05	214.021	$\frac{1}{8}$	4199.74	229.729	$\frac{1}{8}$	4793.70	245.437
$\frac{1}{4}$	3142.04	198.706	$\frac{1}{4}$	3658.44	214.414	$\frac{1}{4}$	4214.11	230.122	$\frac{1}{4}$	4809.05	245.830
$\frac{3}{8}$	3154.47	199.099	$\frac{3}{8}$	3671.86	214.807	$\frac{3}{8}$	4228.51	230.515	$\frac{3}{8}$	4824.43	246.223
$\frac{1}{2}$	3166.93	199.492	$\frac{1}{2}$	3685.29	215.200	$\frac{1}{2}$	4242.93	230.908	$\frac{1}{2}$	4839.83	246.616
$\frac{5}{8}$	3179.41	199.884	$\frac{5}{8}$	3698.76	215.592	$\frac{5}{8}$	4257.37	231.300	$\frac{5}{8}$	4855.26	247.008
$\frac{3}{4}$	3191.91	200.277	$\frac{3}{4}$	3712.24	215.985	$\frac{3}{4}$	4271.84	231.693	$\frac{3}{4}$	4870.71	247.401
$\frac{7}{8}$	3204.44	200.670	$\frac{7}{8}$	3725.75	216.378	$\frac{7}{8}$	4286.33	232.086	$\frac{7}{8}$	4886.18	247.794
64	3217.00	201.062	69	3739.29	216.770	74	4300.85	232.478	79	4901.68	248.186
$\frac{1}{8}$	3229.58	201.455	$\frac{1}{8}$	3752.85	217.163	$\frac{1}{8}$	4315.39	232.871	$\frac{1}{8}$	4917.21	248.579
$\frac{1}{4}$	3242.18	201.848	$\frac{1}{4}$	3766.43	217.556	$\frac{1}{4}$	4329.96	233.264	$\frac{1}{4}$	4932.75	248.972
$\frac{3}{8}$	3254.81	202.240	$\frac{3}{8}$	3780.04	217.948	$\frac{3}{8}$	4344.55	233.656	$\frac{3}{8}$	4948.33	249.364
$\frac{1}{2}$	3267.46	202.633	$\frac{1}{2}$	3793.68	218.341	$\frac{1}{2}$	4359.17	234.049	$\frac{1}{2}$	4963.92	249.757
$\frac{5}{8}$	3280.14	203.026	$\frac{5}{8}$	3807.34	218.734	$\frac{5}{8}$	4373.81	234.442	$\frac{5}{8}$	4979.55	250.150
$\frac{3}{4}$	3292.84	203.419	$\frac{3}{4}$	3821.02	219.127	$\frac{3}{4}$	4388.47	234.835	$\frac{3}{4}$	4995.19	250.543
$\frac{7}{8}$	3305.56	203.811	$\frac{7}{8}$	3834.73	219.519	$\frac{7}{8}$	4403.16	235.227	$\frac{7}{8}$	5010.86	250.935

80 TO
100AREAS AND CIRCUMFERENCES OF
CIRCLES

Diam- eter	Area	Circum- ference	Diam- eter	Area	Circum- ference	Diam- eter	Area	Circum- ference	Diam- eter	Area	Circum- ference
80	5026.56	251.328	85	5674.51	267.036	90	6361.74	282.744	95	7088.24	298.452
$\frac{1}{8}$	5042.28	251.721	$\frac{1}{8}$	5691.22	267.429	$\frac{1}{8}$	6379.42	283.137	$\frac{1}{8}$	7106.90	298.845
$\frac{1}{4}$	5058.03	252.113	$\frac{1}{4}$	5707.94	267.821	$\frac{1}{4}$	6397.13	283.529	$\frac{1}{4}$	7125.59	299.237
$\frac{3}{8}$	5073.79	252.506	$\frac{3}{8}$	5724.69	268.214	$\frac{3}{8}$	6414.86	283.922	$\frac{3}{8}$	7144.31	299.630
$\frac{1}{2}$	5089.59	252.899	$\frac{1}{2}$	5741.47	268.607	$\frac{1}{2}$	6432.62	284.315	$\frac{1}{2}$	7163.04	300.023
$\frac{5}{8}$	5105.41	253.291	$\frac{5}{8}$	5758.27	268.999	$\frac{5}{8}$	6450.40	284.707	$\frac{5}{8}$	7181.81	300.415
$\frac{3}{4}$	5121.25	253.684	$\frac{3}{4}$	5775.10	269.392	$\frac{3}{4}$	6468.21	285.100	$\frac{3}{4}$	7200.60	300.808
$\frac{7}{8}$	5137.12	254.077	$\frac{7}{8}$	5791.94	269.785	$\frac{7}{8}$	6486.04	285.493	$\frac{7}{8}$	7219.41	301.201
81	5153.01	254.470	86	5808.82	270.178	91	6503.90	285.886	96	7238.25	301.594
$\frac{1}{8}$	5168.93	254.862	$\frac{1}{8}$	5825.72	270.570	$\frac{1}{8}$	6521.78	286.278	$\frac{1}{8}$	7257.11	301.986
$\frac{1}{4}$	5184.87	255.255	$\frac{1}{4}$	5842.64	270.963	$\frac{1}{4}$	6539.68	286.671	$\frac{1}{4}$	7275.99	302.379
$\frac{3}{8}$	5200.83	255.648	$\frac{3}{8}$	5859.59	271.356	$\frac{3}{8}$	6557.61	287.064	$\frac{3}{8}$	7294.91	302.772
$\frac{1}{2}$	5216.82	256.040	$\frac{1}{2}$	5876.56	271.748	$\frac{1}{2}$	6575.56	287.456	$\frac{1}{2}$	7313.84	303.164
$\frac{5}{8}$	5232.84	256.433	$\frac{5}{8}$	5893.55	272.141	$\frac{5}{8}$	6593.54	287.849	$\frac{5}{8}$	7332.80	303.557
$\frac{3}{4}$	5248.88	256.826	$\frac{3}{4}$	5910.58	272.534	$\frac{3}{4}$	6611.55	288.242	$\frac{3}{4}$	7351.79	303.950
$\frac{7}{8}$	5264.94	257.218	$\frac{7}{8}$	5927.62	272.926	$\frac{7}{8}$	6629.57	288.634	$\frac{7}{8}$	7370.79	304.342
82	5281.03	257.611	87	5944.69	273.319	92	6647.63	289.027	97	7389.83	304.735
$\frac{1}{8}$	5297.14	258.004	$\frac{1}{8}$	5961.79	273.712	$\frac{1}{8}$	6665.70	289.420	$\frac{1}{8}$	7408.89	305.128
$\frac{1}{4}$	5313.28	258.397	$\frac{1}{4}$	5978.91	274.105	$\frac{1}{4}$	6683.80	289.813	$\frac{1}{4}$	7427.97	305.521
$\frac{3}{8}$	5329.44	258.789	$\frac{3}{8}$	5996.05	274.497	$\frac{3}{8}$	6701.93	290.205	$\frac{3}{8}$	7447.08	305.913
$\frac{1}{2}$	5345.63	259.182	$\frac{1}{2}$	6013.22	274.890	$\frac{1}{2}$	6720.08	290.598	$\frac{1}{2}$	7466.21	306.306
$\frac{5}{8}$	5361.84	259.575	$\frac{5}{8}$	6030.41	275.283	$\frac{5}{8}$	6738.25	290.991	$\frac{5}{8}$	7485.37	306.699
$\frac{3}{4}$	5378.08	259.967	$\frac{3}{4}$	6047.63	275.675	$\frac{3}{4}$	6756.45	291.383	$\frac{3}{4}$	7504.55	307.091
$\frac{7}{8}$	5394.34	260.360	$\frac{7}{8}$	6064.87	276.068	$\frac{7}{8}$	6774.68	291.776	$\frac{7}{8}$	7523.75	307.484
83	5410.62	260.753	88	6082.14	276.461	93	6792.92	292.169	98	7542.98	307.877
$\frac{1}{8}$	5426.93	261.145	$\frac{1}{8}$	6099.43	276.853	$\frac{1}{8}$	6811.20	292.562	$\frac{1}{8}$	7562.24	308.270
$\frac{1}{4}$	5443.26	261.538	$\frac{1}{4}$	6116.74	277.246	$\frac{1}{4}$	6829.49	292.954	$\frac{1}{4}$	7581.52	308.662
$\frac{3}{8}$	5459.62	261.931	$\frac{3}{8}$	6134.08	277.638	$\frac{3}{8}$	6847.82	293.347	$\frac{3}{8}$	7600.82	309.055
$\frac{1}{2}$	5476.01	262.324	$\frac{1}{2}$	6151.45	278.032	$\frac{1}{2}$	6866.16	293.740	$\frac{1}{2}$	7620.15	309.448
$\frac{5}{8}$	5492.41	262.716	$\frac{5}{8}$	6168.84	278.424	$\frac{5}{8}$	6884.53	294.132	$\frac{5}{8}$	7639.50	309.840
$\frac{3}{4}$	5508.84	263.109	$\frac{3}{4}$	6186.25	278.817	$\frac{3}{4}$	6902.93	294.525	$\frac{3}{4}$	7658.88	310.233
$\frac{7}{8}$	5525.30	263.502	$\frac{7}{8}$	6203.69	279.210	$\frac{7}{8}$	6921.35	294.918	$\frac{7}{8}$	7678.28	310.626
84	5541.78	263.894	89	6221.15	279.602	94	6939.79	295.310	99	7697.71	311.018
$\frac{1}{8}$	5558.29	264.287	$\frac{1}{8}$	6238.64	279.995	$\frac{1}{8}$	6958.26	295.703	$\frac{1}{8}$	7717.16	311.411
$\frac{1}{4}$	5574.82	264.680	$\frac{1}{4}$	6256.15	280.388	$\frac{1}{4}$	6976.76	296.096	$\frac{1}{4}$	7736.63	311.804
$\frac{3}{8}$	5591.37	265.072	$\frac{3}{8}$	6273.69	280.780	$\frac{3}{8}$	6995.28	296.488	$\frac{3}{8}$	7756.13	312.196
$\frac{1}{2}$	5607.95	265.465	$\frac{1}{2}$	6291.25	281.173	$\frac{1}{2}$	7013.82	296.881	$\frac{1}{2}$	7775.66	312.589
$\frac{5}{8}$	5624.56	265.858	$\frac{5}{8}$	6308.84	281.566	$\frac{5}{8}$	7032.39	297.274	$\frac{5}{8}$	7795.21	312.982
$\frac{3}{4}$	5641.18	266.251	$\frac{3}{4}$	6326.45	281.959	$\frac{3}{4}$	7050.98	297.667	$\frac{3}{4}$	7814.78	313.375
$\frac{7}{8}$	5657.84	266.643	$\frac{7}{8}$	6344.08	282.351	$\frac{7}{8}$	7069.59	298.059	$\frac{7}{8}$	7834.38	313.767
									100	7854.00	314.160

LENGTH OF CIRCULAR ARCS FOR UNIT RADIUS

By the use of this table, the length of any arc may be found if the length of the radius and the angle of the segment are known.

Example:—Required the length of arc of segment of $32^{\circ} 15' 27''$ with radius of 24 feet 3 inches.

From table: Length of arc (Radius 1) for $32^{\circ} = .5585054$

$15' = .0043633$

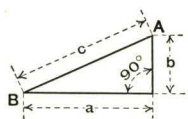
$27'' = .0001309$

$.5629996$

$.5629996 \times 24.25$ (length of radius) = 13.65274 feet.

DEGREES					MINUTES		SECONDS		
1°	.017 4533	61°	1.064 6508	121°	2.111 8484	1'	.000 2909	1"	.000 0048
2	.034 9066	62	1.082 1041	122	2.129 3017	2	.000 5818	2	.000 0097
3	.052 3599	63	1.099 5574	123	2.146 7550	3	.000 8727	3	.000 0145
4	.069 8132	64	1.117 0107	124	2.164 2083	4	.001 1636	4	.000 0194
5	.087 2665	65	1.134 4640	125	2.181 6616	5	.001 4544	5	.000 0242
6	.104 7198	66	1.151 9173	126	2.199 1149	6	.001 7453	6	.000 0291
7	.122 1730	67	1.169 3706	127	2.216 5682	7	.002 0362	7	.000 0339
8	.139 6263	68	1.186 8239	128	2.234 0214	8	.002 3271	8	.000 0388
9	.157 0796	69	1.204 2772	129	2.251 4747	9	.002 6180	9	.000 0436
10	.174 5329	70	1.221 7305	130	2.268 9280	10	.002 9089	10	.000 0485
11	.191 9862	71	1.239 1838	131	2.286 3813	11	.003 1998	11	.000 0533
12	.209 4395	72	1.256 6371	132	2.303 8346	12	.003 4907	12	.000 0582
13	.226 8928	73	1.274 0904	133	2.321 2879	13	.003 7815	13	.000 0630
14	.244 3461	74	1.291 5436	134	2.338 7412	14	.004 0724	14	.000 0679
15	.261 7994	75	1.308 9969	135	2.356 1945	15	.004 3633	15	.000 0727
16	.279 2527	76	1.326 4502	136	2.373 6478	16	.004 6542	16	.000 0776
17	.296 7060	77	1.343 9035	137	2.391 1011	17	.004 9451	17	.000 0824
18	.314 1593	78	1.361 3568	138	2.408 5544	18	.005 2360	18	.000 0873
19	.331 6126	79	1.378 8101	139	2.426 0077	19	.005 5269	19	.000 0921
20	.349 0659	80	1.396 2634	140	2.443 4610	20	.005 8178	20	.000 0970
21	.366 5191	81	1.413 7167	141	2.460 9142	21	.006 1087	21	.000 1018
22	.383 9724	82	1.431 1700	142	2.478 3675	22	.006 3995	22	.000 1067
23	.401 4257	83	1.448 6233	143	2.495 8208	23	.006 6904	23	.000 1115
24	.418 8790	84	1.466 0766	144	2.513 2741	24	.006 9813	24	.000 1164
25	.436 3323	85	1.483 5299	145	2.530 7274	25	.007 2722	25	.000 1212
26	.453 7856	86	1.500 9832	146	2.548 1807	26	.007 5631	26	.000 1261
27	.471 2389	87	1.518 4364	147	2.565 6340	27	.007 8540	27	.000 1309
28	.488 6922	88	1.535 8897	148	2.583 0873	28	.008 1449	28	.000 1357
29	.506 1455	89	1.553 3430	149	2.600 5406	29	.008 4358	29	.000 1406
30	.523 5988	90	1.570 7963	150	2.617 9939	30	.008 7266	30	.000 1454
31	.541 0521	91	1.588 2496	151	2.635 4472	31	.009 0175	31	.000 1503
32	.558 5054	92	1.605 7029	152	2.652 9005	32	.009 3084	32	.000 1551
33	.575 9587	93	1.623 1562	153	2.670 3538	33	.009 5993	33	.000 1600
34	.593 4119	94	1.640 6095	154	2.687 8070	34	.009 8902	34	.000 1648
35	.610 8652	95	1.658 0628	155	2.705 2603	35	.010 1811	35	.000 1697
36	.628 3185	96	1.675 5161	156	2.722 7136	36	.010 4720	36	.000 1745
37	.645 7718	97	1.692 9694	157	2.740 1669	37	.010 7629	37	.000 1794
38	.663 2251	98	1.710 4227	158	2.757 6202	38	.011 0538	38	.000 1842
39	.680 6784	99	1.727 8760	159	2.775 0735	39	.011 3446	39	.000 1891
40	.698 1317	100	1.745 3293	160	2.792 5268	40	.011 6355	40	.000 1939
41	.715 5850	101	1.762 7825	161	2.809 9801	41	.011 9264	41	.000 1988
42	.733 0383	102	1.780 2358	162	2.827 4334	42	.012 2173	42	.000 2036
43	.750 4916	103	1.797 6891	163	2.844 8867	43	.012 5082	43	.000 2085
44	.767 9449	104	1.815 1424	164	2.862 3400	44	.012 7991	44	.000 2133
45	.785 3982	105	1.832 5957	165	2.879 7933	45	.013 0900	45	.000 2182
46	.802 8515	106	1.850 0490	166	2.897 2466	46	.013 3809	46	.000 2230
47	.820 3047	107	1.867 5023	167	2.914 6999	47	.013 6717	47	.000 2279
48	.837 7580	108	1.884 9556	168	2.932 1531	48	.013 9626	48	.000 2327
49	.855 2113	109	1.902 4089	169	2.949 6064	49	.014 2535	49	.000 2376
50	.872 6646	110	1.919 8622	170	2.967 0597	50	.014 5444	50	.000 2424
51	.890 1179	111	1.937 3155	171	2.984 5130	51	.014 8353	51	.000 2473
52	.907 5712	112	1.954 7688	172	3.001 9663	52	.015 1262	52	.000 2521
53	.925 0245	113	1.972 2221	173	3.019 4196	53	.015 4171	53	.000 2570
54	.942 4778	114	1.989 6753	174	3.036 8729	54	.015 7080	54	.000 2618
55	.959 9311	115	2.007 1286	175	3.054 3262	55	.015 9989	55	.000 2666
56	.977 3844	116	2.024 5819	176	3.071 7795	56	.016 2897	56	.000 2715
57	.994 8377	117	2.042 0352	177	3.089 2328	57	.016 5806	57	.000 2763
58	1.012 2910	118	2.059 4885	178	3.106 6861	58	.016 8715	58	.000 2812
59	1.029 7443	119	2.076 9418	179	3.124 1394	59	.017 1624	59	.000 2860
60	1.047 1976	120	2.094 3951	180	3.141 5927	60	.017 4533	60	.000 2909

MENSURATION OF PLANE FIGURES



RIGHT TRIANGLE

$$A + B = 90^\circ$$

$$c = \sqrt{a^2 + b^2}$$

$$\text{Area} = \frac{1}{2} ab$$

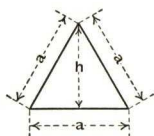
$$\tan B = \cot A = \frac{b}{a}$$

$$a = \sqrt{c^2 - b^2}$$

$$= \frac{1}{2} a^2 \tan B$$

$$b = \sqrt{c^2 - a^2}$$

$$\text{Perimeter} = a + b + c$$



EQUILATERAL TRIANGLE

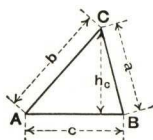
$$\text{All Angles} = 60^\circ$$

$$\text{Area} = \frac{1}{2} a h = \frac{\sqrt{3}}{4} a^2$$

$$h = \frac{\sqrt{3}}{2} a = .8660254 a$$

$$= .4330127 a^2$$

$$\text{Perimeter} = 3a = 3.464102 h$$



OBLIQUE TRIANGLE

$$A + B + C = 180^\circ \quad A = 180 - (B + C)^\circ$$

I

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \quad \therefore a = b \frac{\sin A}{\sin B} \quad s = \frac{1}{2} (a + b + c) \quad \text{II}$$

$$\frac{a+b}{a-b} = \frac{\tan \frac{1}{2}(A+B)}{\tan \frac{1}{2}(A-B)}; \left(\frac{b+c}{b-c} \right) = \frac{\tan \frac{1}{2}(B+C)}{\tan \frac{1}{2}(B-C)}; \left(\frac{c+a}{c-a} \right) = \frac{\tan \frac{1}{2}(C+A)}{\tan \frac{1}{2}(C-A)} \quad \text{III}$$

$$* a^2 = b^2 + c^2 - 2bc \cos A \quad \textcircled{1}$$

$$* a = b \cos C + c \cos B$$

$$* \cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

$$b^2 = c^2 + a^2 - 2ca \cos B \quad \textcircled{2}$$

$$b = c \cos A + a \cos C$$

$$\cos B = \frac{c^2 + a^2 - b^2}{2ca}$$

$$c^2 = a^2 + b^2 - 2ab \cos C \quad \textcircled{3}$$

$$c = a \cos B + b \cos A$$

$$\cos C = \frac{a^2 + b^2 - c^2}{2ab}$$

IV

$$\sin \frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{bc}} \quad \cos \frac{A}{2} = \sqrt{\frac{s(s-a)}{bc}} \quad \tan \frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}} = \frac{r}{s-a} \quad \text{V}$$

$$h_c = a \sin B = b \sin A = \frac{2}{c} \sqrt{s(s-a)(s-b)(s-c)} \quad \text{VI}$$

$$r = \sqrt{\frac{(s-a)(s-b)(s-c)}{s}} = (s-a) \tan \frac{A}{2} \quad r = \text{Radius of Inscribed Circle} \quad \text{VII}$$

$$R = \frac{a}{2 \sin A} = \frac{abc}{4(\text{Area})} \quad R = \text{Radius of Circumscribed Circle} \quad \text{VIII}$$

$$\text{Area} = \frac{1}{2} ch_c = \frac{1}{2} ac \sin B = \frac{a^2 \sin B \sin C}{2 \sin A} = \sqrt{s(s-a)(s-b)(s-c)} = rs \quad \text{IX}$$

SOLUTION OF TRIANGLES

For Area, see IX

Given	Sought	
a, b, c	A, B, C	See II and V
a, A, B	C	$180^\circ - (A + B)$
	b, c	See II
a, b, A	B	See II
	C	$180^\circ - (A + B)$
	c	See II or IV
a, b, C	A	$\tan A = \frac{a \sin C}{b - a \cos C}$
	B	$180^\circ - (A + C)$
	c	See IV

$$\text{or } \begin{cases} \frac{1}{2} (A + B) = 90^\circ - \frac{C}{2} \\ \tan \frac{1}{2} (A - B) = \frac{a - b}{a + b} \cot \frac{C}{2} \end{cases}$$

* It should be noted that $\textcircled{2}$ is derived from $\textcircled{1}$ by changing a to b, b to c, c to a, and A to B. Hereafter where 3 equations of the same form are obtained by rotating letters in this fashion, a * will be used. The three sets of equations in IV illustrate the procedure. Reference to the drawing will show the method.

MENSURATION OF PLANE FIGURES

SQUARE

Side = a
Diagonal = d

$$d = a\sqrt{2} = 1.4142136 a$$

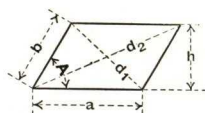
$$\text{Area} = a^2$$

RECTANGLE

Base = b
Side = a
Diagonal = d

$$d = \sqrt{a^2 + b^2}$$

$$\text{Area} = ab$$



PARALLELOGRAM

Opposite Sides Parallel

$$d_1 = \sqrt{a^2 + b^2 - 2ab \cos A}$$

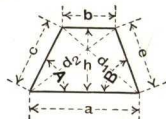
$$d_2 = \sqrt{a^2 + b^2 + 2ab \cos A}$$

$$\sin A = \frac{h}{b}$$

$$\text{Area} = ah = ab \sin A$$

TRAPEZOID

Two opposite sides Parallel Isosceles Trapezoid (A = B)



$$\text{Area} = \frac{1}{2} h (a + b)$$

$$a = c \cos A + b + e \cos B$$

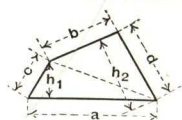
$$\sin A = \frac{h}{c} \quad \sin B = \frac{h}{e}$$

$$\text{Area} = \frac{1}{2} h (a + b) = \frac{1}{2} c \sin A (a + b)$$

$$= c \sin A (a - c \cos A)$$

$$= c \sin A (b + c \cos A)$$

Solve as 2 triangles



TRAPEZIUM

No sides parallel

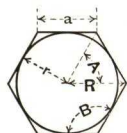
$$\text{Area} = \frac{1}{2} [ah_1 + bh_2]$$

Solve as two triangles

REGULAR POLYGON

All sides equal; all angles equal.
n = Number of sides.

$$A = \frac{360}{n} \quad B = \frac{n-2}{n} 180^\circ$$



n =	3	4	6	8	n
a	3.4641016 r	2 r	1.1547005 r	.8284272 r	2 r tan A/2
r	.2886752 a	.5 a	.8660254 a	1.2071068 a	$\frac{1}{2} a \cot A/2$
R	.5773503 a	.7071068 a	a	1.306563 a	$\frac{1}{2} a \csc A/2$
Area	.4330127 a ²	a ²	2.598076 a ²	4.828427 a ²	$\frac{1}{4} na^2 \cot A/2$

CIRCLE

A = Angle, degrees A_r = Angle, radians

C (Circumference) = $\pi D = 2\pi R$

Area (Circle) = $\pi R^2 = \frac{\pi}{4} D^2 = \frac{1}{2} RC = \frac{1}{4} DC$

$$c = RA_r = \frac{1}{2} DA_r = D \cos^{-1} \frac{d}{R} = D \tan^{-1} \frac{l}{2d}$$

" (Sector) = $\frac{1}{2} RC = \frac{1}{2} R^2 A_r = \frac{1}{8} D^2 A_r$

$$l = 2 \sqrt{R^2 - d^2} = 2 R \sin \frac{A}{2}$$

$$= 2d \tan \frac{A}{2} = 2d \tan \frac{C}{D}$$

" (segment) = Area (sector) - Area (Triangle)

$$= \frac{1}{2} R^2 (A_r - \sin A) = \frac{1}{2} R \left(c - R \sin \frac{C}{R} \right)$$

$$d = \frac{1}{2} \sqrt{4R^2 - l^2} = \frac{1}{2} \sqrt{D^2 - l^2} = R \cos \frac{A}{2}$$

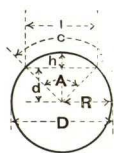
$$= \frac{1}{2} l \cot \frac{A}{2} = \frac{1}{2} l \cot \frac{C}{D} \quad h = R - d$$

$$= R^2 \sin^{-1} \frac{l}{2R} - \frac{l}{4} \sqrt{4R^2 - l^2}$$

$$= R^2 \cos^{-1} \frac{d}{R} - d \sqrt{R^2 - d^2}$$

$$A_r = \frac{c}{R} = \frac{2c}{D} = 2 \cos^{-1} \frac{d}{R} = 2 \tan^{-1} \frac{l}{2d} = 2 \sin^{-1} \frac{l}{D}$$

$$= R^2 \cos^{-1} \frac{R-h}{R} - (R-h) \sqrt{2Rh - h^2}$$

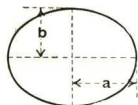


MENSURATION OF PLANE FIGURES

ELLIPSE

$$U = \left(\frac{a-b}{a+b} \right)^2$$

$$\text{Ellipticity} = e = \frac{\sqrt{a^2 - b^2}}{a} \quad \text{Area} = \pi ab$$



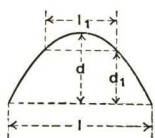
$$\text{Perimeter} = s = \pi(a+b) \left[1 + \frac{1}{4} U + \frac{1}{64} U^2 + \frac{1}{256} U^3 + \frac{1}{512} U^4 + \frac{1}{1024} U^5 + \dots \right]$$

$$= 4a \left[\int_0^{\frac{\pi}{2}} (1 - \sin^2 \theta \sin^2 \phi)^{\frac{1}{2}} d\phi \right] \quad \text{where } \theta = \sin^{-1} e$$

Values of [...] (elliptic integrals) for various values of θ are found in Smithsonian Physical Tables and save calculating series.

PARABOLA

Length of arc (s)



$$\text{Area} = \frac{2}{3} ld$$

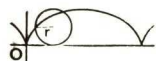
$$= \frac{1}{2} \sqrt{16d^2 + l^2} + .28782314 \frac{l^2}{d} \log_{10} \left(\frac{4d + \sqrt{16d^2 + l^2}}{l} \right)$$

$$\text{Height of segment } d_1 = \frac{d}{l^2} (l^2 - l_1^2)$$

$$= l \left[1 + \frac{2}{3} v - \frac{2}{5} v^2 + \dots \right]$$

$$\text{Width of " } l_1 = l \sqrt{\frac{d - d_1}{d}} \quad v = \left(\frac{2d}{l} \right)^2$$

CYCLOID



r = Radius of Generating Circle

$$\text{Area} = 3 \pi r^2$$

$$\text{Arc Length (s)} = 8r$$

CATENARY

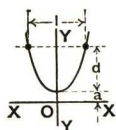
From table of hyperbolic functions find a solution of equation,

$$\cosh x = \frac{2xd}{l} + 1$$

$$x = \frac{l}{2a} \text{ or } a = \frac{l}{2x}$$

$$\text{Length of Curve} = 2a \sinh x = \frac{l}{x} \sinh x$$

$$\text{Plot curve } y = a \cosh x \text{ where } x < \frac{l}{2a}$$



AREA BY APPROXIMATION

Divide l into n equal parts, by parallel lines.

Then $h = \frac{l}{n}$. n preferably 10 or greater.

Measure $y_0, y_1, y_2, \dots, y_{n-1}$ and y_n .

Area, by Trapezoidal Rule (Boundary replaced by line segments)
 $A_t = h \left[\frac{1}{2} (y_0 + y_n) + y_1 + y_2 + \dots + y_{n-1} \right]$ n even or odd

Area, by Durand's Rule

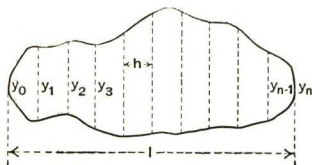
$$A_d = h \left[0.4(y_0 + y_n) + 1.1(y_1 + y_{n-1}) + y_2 + y_3 + \dots + y_{n-2} \right]$$

n even or odd

Area, by Simpson's Rule (Boundary replaced by 2d degree curves)

$$A_s = \frac{h}{3} \left[(y_0 + y_n) + 4(y_1 + y_3 + \dots + y_{n-1}) + 2(y_2 + y_4 + \dots + y_{n-2}) \right]$$

n even.



A_t least accurate,
 A_s most "

TRIGONOMETRIC FORMULAS

$$\sin A = \frac{1}{\operatorname{cosec} A} = \sqrt{1 - \cos^2 A} = \tan A \cos A = 2 \sin \frac{1}{2} A \cos \frac{1}{2} A$$

$$= \operatorname{vers} A \cot \frac{1}{2} A = \sqrt{\frac{1}{2} \operatorname{vers} 2 A} = \sqrt{\frac{1}{2} (1 - \cos 2 A)}$$

$$\cos A = \frac{1}{\sec A} = \sqrt{1 - \sin^2 A} = \cot A \sin A = 1 - \operatorname{vers} A = 2 \cos^2 \frac{1}{2} A - 1$$

$$= 1 - 2 \sin^2 \frac{1}{2} A = \cos^2 \frac{1}{2} A - \sin^2 \frac{1}{2} A = \sqrt{\frac{1}{2} + \frac{1}{2} \cos 2 A}$$

$$\tan A = \frac{1}{\cot A} = \frac{\sin A}{\cos A} = \sqrt{\sec^2 A - 1} = \sqrt{\frac{1}{\cos^2 A} - 1} = \frac{\sqrt{1 - \cos^2 A}}{\cos A}$$

$$= \frac{\sin 2 A}{1 + \cos 2 A} = \frac{1 - \cos 2 A}{\sin 2 A} = \frac{\operatorname{vers} 2 A}{\sin 2 A} = \operatorname{exsec} A \cot \frac{1}{2} A$$

$$\cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A} = \sqrt{\operatorname{cosec}^2 A - 1} = \frac{\sin 2 A}{1 - \cos 2 A} = \frac{\sin 2 A}{\operatorname{vers} 2 A}$$

$$= \frac{1 + \cos 2 A}{\sin 2 A} = \frac{\tan \frac{1}{2} A}{\operatorname{exsec} A}$$

$$\operatorname{vers} A = 1 - \cos A = \sin A \tan \frac{1}{2} A = 2 \sin^2 \frac{1}{2} A = \operatorname{exsec} A \cos A$$

$$\operatorname{exsec} A = \sec A - 1 = \tan A \tan \frac{1}{2} A = \frac{\operatorname{vers} A}{\cos A}$$

$$\sin \frac{1}{2} A = \sqrt{\frac{1 - \cos A}{2}} = \sqrt{\frac{\operatorname{vers} A}{2}} \quad \cos \frac{1}{2} A = \sqrt{\frac{1 + \cos A}{2}}$$

$$\tan \frac{1}{2} A = \frac{\tan A}{1 + \sec A} = \operatorname{cosec} A - \cot A = \frac{1 - \cos A}{\sin A} = \sqrt{\frac{1 - \cos A}{1 + \cos A}}$$

$$\cot \frac{1}{2} A = \frac{\sin A}{\operatorname{vers} A} = \frac{1 + \cos A}{\sin A} = \frac{1}{\operatorname{cosec} A - \cot A}$$

$$\operatorname{vers} \frac{1}{2} A = \frac{\frac{1}{2} \operatorname{vers} A}{1 + \sqrt{1 - \frac{1}{2} \operatorname{vers} A}} = \frac{1 - \cos A}{2 + \sqrt{2(1 + \cos A)}}$$

$$\operatorname{exsec} \frac{1}{2} A = \frac{1 - \cos A}{(1 + \cos A) + \sqrt{2(1 + \cos A)}} \quad \sin 2 A = 2 \sin A \cos A$$

$$\cos 2 A = 2 \cos^2 A - 1 = \cos^2 A - \sin^2 A = 1 - 2 \sin^2 A$$

$$\tan 2 A = \frac{2 \tan A}{1 - \tan^2 A} \quad \cot 2 A = \frac{\cot^2 A - 1}{2 \cot A}$$

$$\operatorname{vers} 2 A = 2 \sin^2 A = 2 \sin A \cos A \tan A$$

$$\operatorname{exsec} 2 A = \frac{2 \tan^2 A}{1 - \tan^2 A}$$

$$\sin 3 A = 3 \sin A - 4 \sin^3 A$$

$$\cos 3 A = 4 \cos^3 A - 3 \cos A$$

$$\tan 3 A = \frac{3 \tan A - \tan^3 A}{1 - 3 \tan^2 A}$$

$$\sin 4 A = 4 \sin A \cos A - 8 \sin^3 A \cos A$$

$$\cos 4 A = 1 - 8 \cos^2 A + 8 \cos^4 A$$

$$\tan 4 A = \frac{4 \tan A - 4 \tan^3 A}{1 - 6 \tan^2 A + \tan^4 A}$$

$$\sin (A+B) = \sin A \cos B + \sin B \cos A$$

$$\sin (A-B) = \sin A \cos B - \sin B \cos A$$

$$\cos (A+B) = \cos A \cos B - \sin A \sin B$$

$$\cos (A-B) = \cos A \cos B + \sin A \sin B$$

$$\sin A + \sin B = 2 \sin \frac{1}{2} (A+B) \cos \frac{1}{2} (A-B)$$

$$\sin A - \sin B = 2 \cos \frac{1}{2} (A+B) \sin \frac{1}{2} (A-B)$$

$$\cos A + \cos B = 2 \cos \frac{1}{2} (A+B) \cos \frac{1}{2} (A-B)$$

$$\cos B - \cos A = 2 \sin \frac{1}{2} (A+B) \sin \frac{1}{2} (A-B)$$

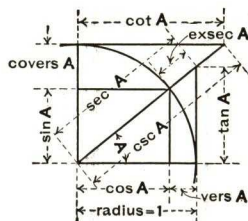
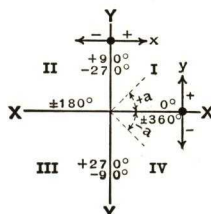
$$\sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A$$

$$= \sin (A+B) \sin (A-B)$$

$$\cos^2 A - \sin^2 B = \cos (A+B) \cos (A-B)$$

$$\tan A + \tan B = \frac{\sin (A+B)}{\cos A \cos B}$$

$$\tan A - \tan B = \frac{\sin (A-B)}{\cos A \cos B}$$



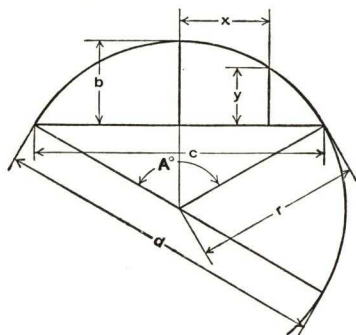
Range of Function Values

Quadrant	I	II	III	IV
Angles $\pm$	$0^\circ - 90^\circ$ $270^\circ - 360^\circ$	$90^\circ - 180^\circ$ $180^\circ - 270^\circ$	$180^\circ - 270^\circ$ $90^\circ - 180^\circ$	$270^\circ - 360^\circ$ $0^\circ - 90^\circ$
sin $\pm A$	0 to +1 +1 to 0	+1 to 0 0 to +1	0 to -1 -1 to 0	-1 to 0 0 to -1
cos $\pm A$	+1 to 0 0 to +1	0 to -1 -1 to 0	-1 to 0 0 to -1	0 to +1 +1 to 0
tan $\pm A$	0 to + ∞ + ∞ to 0	- ∞ to 0 0 to - ∞	0 to + ∞ + ∞ to 0	- ∞ to 0 0 to - ∞
cot $\pm A$	+ ∞ to 0 0 to + ∞	0 to - ∞ - ∞ to 0	0 to + ∞ + ∞ to 0	- ∞ to 0 0 to - ∞

Functions of Angles Greater than 90°

Angle A	sin A	cos A	tan A	cot A
$0^\circ + a$	$\pm \sin a$	$+$ cos a	$\pm \tan a$	$\pm \cot a$
$90^\circ + a$	$+$ cos a	$\mp \sin a$	$\mp \cot a$	$\mp \tan a$
$180^\circ + a$	$\mp \sin a$	$-$ cos a	$\pm \tan a$	$\pm \cot a$
$270^\circ + a$	$-$ cos a	$\pm \sin a$	$\mp \cot a$	$\mp \tan a$
$360^\circ + a$	$\pm \sin a$	$+$ cos a	$\pm \tan a$	$\pm \cot a$

PROPERTIES OF THE CIRCLE



Circumference = $6.28318 r = 3.14159 d$
 Diameter = $0.31831 \text{ circumference}$
 Area = $3.14159 r^2$

Arc $a = \frac{\pi r A^\circ}{180^\circ} = 0.017453 r A^\circ$

Angle $A^\circ = \frac{180^\circ a}{\pi r} = 57.29578 \frac{a}{r}$

Radius $r = \frac{4 b^2 + c^2}{8 b}$

Chord $c = 2 \sqrt{2 b r - b^2} = 2 r \sin \frac{A}{2}$

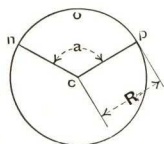
Rise $b = r - \frac{1}{2} \sqrt{4 r^2 - c^2} = \frac{c}{2} \tan \frac{A}{4}$

$= 2 r \sin^2 \frac{A}{4} = r + y - \sqrt{r^2 - x^2}$

$y = b - r + \sqrt{r^2 - x^2}$

$x = \sqrt{r^2 - (r + y - b)^2}$

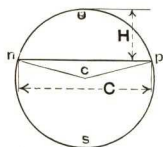
Diameter of circle of equal periphery as square = $1.27324 \text{ side of square}$
 Side of square of equal periphery as circle = $0.78540 \text{ diameter of circle}$
 Diameter of circle circumscribed about square = $1.41421 \text{ side of square}$
 Side of square inscribed in circle = $0.70711 \text{ diameter of circle}$



CIRCULAR SECTOR

R = radius of circle a = angle ncp in degrees

Area of Sector ncpo = $\frac{1}{2} (\text{length of arc nop} \times R) = \text{Area of Circle} \times \frac{a}{360}$
 $= 0.0087266 \times R^2 \times a$



CIRCULAR SEGMENT

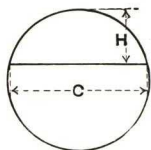
R = radius of circle C = chord H = rise

Area of Segment nop = Area of Sector ncpo - Area of triangle ncp
 $= \frac{(\text{Length of arc nop} \times R) - C(R - H)}{2}$

Area of Segment nsp = Area of Circle - Area of Segment nop

CIRCULAR SEGMENT, From Table I, page 267

Given: Rise, H , and Chord, C



Area = Coefficient $\times H \times C$

Coefficient found opposite $\frac{H}{C}$

Interpolate for intermediate values of $\frac{H}{C}$

Example:

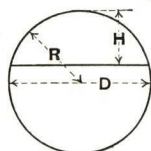
RISE = 1.49 CHORD = 3.52

$\frac{H}{C} = \frac{1.49}{3.52} = 0.4233$ Coeff. = 0.7542

Area = $H \times C \times \text{Coeff.} = 1.49 \times 3.52 \times 0.7542 = 3.9556$

CIRCULAR SEGMENT, From Table II, pages 268, 269

Given: RISE, H , and DIAMETER, $D = 2R$



Area = Coefficient $\times D^2$

Coefficient opposite $\frac{H}{D}$

Interpolate for intermediate values of $\frac{H}{D}$

Example:

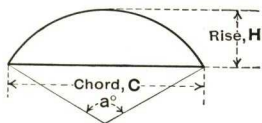
RISE = $2\frac{7}{16}$ and DIAMETER = $5\frac{3}{32}$

$\frac{H}{D} = 2.4375 \div 5.09375 = 0.478528$

Coefficient = 0.371233

Area = Coef. $\times D^2 = 0.371233 \times 25.94629 = 9.6321$

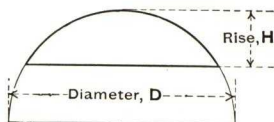
AREAS OF CIRCULAR SEGMENTS
TABLE I—FOR RATIOS OF RISE AND CHORD



$$\text{Area} = C \times H \times \text{coefficient}$$

a	Coefficient	H C	a	Coefficient	H C	a	Coefficient	H C	a	Coefficient	H C
1	.6667	.0022	46	.6722	.1017	91	.6895	.2097	136	.7239	.3373
2	.6667	.0044	47	.6724	.1040	92	.6901	.2122	137	.7249	.3404
3	.6667	.0066	48	.6727	.1063	93	.6906	.2148	138	.7260	.3436
4	.6667	.0087	49	.6729	.1086	94	.6912	.2174	139	.7270	.3469
5	.6667	.0109	50	.6732	.1109	95	.6918	.2200	140	.7281	.3501
6	.6667	.0131	51	.6734	.1131	96	.6924	.2226	141	.7292	.3534
7	.6668	.0153	52	.6737	.1154	97	.6930	.2252	142	.7303	.3567
8	.6668	.0175	53	.6740	.1177	98	.6936	.2279	143	.7314	.3600
9	.6669	.0197	54	.6743	.1200	99	.6942	.2305	144	.7325	.3633
10	.6670	.0218	55	.6746	.1224	100	.6948	.2332	145	.7336	.3666
11	.6670	.0240	56	.6749	.1247	101	.6954	.2358	146	.7348	.3700
12	.6671	.0262	57	.6752	.1270	102	.6961	.2385	147	.7360	.3734
13	.6672	.0284	58	.6755	.1293	103	.6967	.2412	148	.7372	.3768
14	.6672	.0306	59	.6758	.1316	104	.6974	.2439	149	.7384	.3802
15	.6673	.0328	60	.6761	.1340	105	.6980	.2466	150	.7396	.3837
16	.6674	.0350	61	.6764	.1363	106	.6987	.2493	151	.7408	.3871
17	.6674	.0372	62	.6768	.1387	107	.6994	.2520	152	.7421	.3906
18	.6675	.0394	63	.6771	.1410	108	.7001	.2548	153	.7434	.3942
19	.6676	.0416	64	.6775	.1434	109	.7008	.2575	154	.7447	.3977
20	.6677	.0437	65	.6779	.1457	110	.7015	.2603	155	.7460	.4013
21	.6678	.0459	66	.6782	.1481	111	.7022	.2631	156	.7473	.4049
22	.6679	.0481	67	.6786	.1505	112	.7030	.2659	157	.7486	.4085
23	.6680	.0504	68	.6790	.1529	113	.7037	.2687	158	.7500	.4122
24	.6681	.0526	69	.6794	.1553	114	.7045	.2715	159	.7514	.4159
25	.6682	.0548	70	.6797	.1577	115	.7052	.2743	160	.7528	.4196
26	.6684	.0570	71	.6801	.1601	116	.7060	.2772	161	.7542	.4233
27	.6685	.0592	72	.6805	.1625	117	.7068	.2800	162	.7557	.4270
28	.6687	.0614	73	.6809	.1649	118	.7076	.2829	163	.7571	.4308
29	.6688	.0636	74	.6814	.1673	119	.7084	.2858	164	.7586	.4346
30	.6690	.0658	75	.6818	.1697	120	.7092	.2887	165	.7601	.4385
31	.6691	.0681	76	.6822	.1722	121	.7100	.2916	166	.7616	.4424
32	.6693	.0703	77	.6826	.1746	122	.7109	.2945	167	.7632	.4463
33	.6694	.0725	78	.6831	.1771	123	.7117	.2975	168	.7648	.4502
34	.6696	.0747	79	.6835	.1795	124	.7126	.3004	169	.7664	.4542
35	.6698	.0770	80	.6840	.1820	125	.7134	.3034	170	.7680	.4582
36	.6700	.0792	81	.6844	.1845	126	.7143	.3064	171	.7696	.4622
37	.6702	.0814	82	.6849	.1869	127	.7152	.3094	172	.7712	.4663
38	.6704	.0837	83	.6854	.1894	128	.7161	.3124	173	.7729	.4704
39	.6706	.0859	84	.6859	.1919	129	.7170	.3155	174	.7746	.4745
40	.6708	.0882	85	.6864	.1944	130	.7180	.3185	175	.7763	.4787
41	.6710	.0904	86	.6869	.1970	131	.7189	.3216	176	.7781	.4828
42	.6712	.0927	87	.6874	.1995	132	.7199	.3247	177	.7799	.4871
43	.6714	.0949	88	.6879	.2020	133	.7209	.3278	178	.7817	.4914
44	.6717	.0972	89	.6884	.2046	134	.7219	.3309	179	.7835	.4957
45	.6719	.0995	90	.6890	.2071	135	.7229	.3341	180	.7854	.5000

AREAS OF CIRCULAR SEGMENTS
TABLE II, FOR RATIOS OF RISE AND DIAMETER

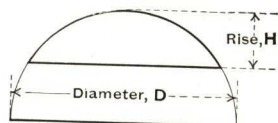


$$\text{Area} = D^2 \times \text{Coefficient}$$

$\frac{H}{D}$	Coefficient	$\frac{H}{D}$	Coefficient	$\frac{H}{D}$	Coefficient	$\frac{H}{D}$	Coefficient	$\frac{H}{D}$	Coefficient
.001	.000042	.051	.015119	.101	.041477	.151	.074590	.201	.112625
.002	.000119	.052	.015561	.102	.042081	.152	.075307	.202	.113427
.003	.000219	.053	.016008	.103	.042687	.153	.076026	.203	.114231
.004	.000337	.054	.016458	.104	.043296	.154	.076747	.204	.115036
.005	.000471	.055	.016912	.105	.043908	.155	.077470	.205	.115842
.006	.000619	.056	.017369	.106	.044523	.156	.078194	.206	.116651
.007	.000779	.057	.017831	.107	.045140	.157	.078921	.207	.117460
.008	.000952	.058	.018297	.108	.045759	.158	.079650	.208	.118271
.009	.001135	.059	.018766	.109	.046381	.159	.080380	.209	.119084
.010	.001329	.060	.019239	.110	.047006	.160	.081112	.210	.119898
.011	.001533	.061	.019716	.111	.047633	.161	.081847	.211	.120713
.012	.001746	.062	.020197	.112	.048262	.162	.082582	.212	.121530
.013	.001969	.063	.020681	.113	.048894	.163	.083320	.213	.122348
.014	.002199	.064	.021168	.114	.049529	.164	.084060	.214	.123167
.015	.002438	.065	.021660	.115	.050165	.165	.084801	.215	.123988
.016	.002685	.066	.022155	.116	.050805	.166	.085545	.216	.124811
.017	.002940	.067	.022653	.117	.051446	.167	.086290	.217	.125634
.018	.003202	.068	.023155	.118	.052090	.168	.087037	.218	.126459
.019	.003472	.069	.023660	.119	.052737	.169	.087785	.219	.127286
.020	.003749	.070	.024168	.120	.053385	.170	.088536	.220	.128114
.021	.004032	.071	.024680	.121	.054037	.171	.089288	.221	.128943
.022	.004322	.072	.025196	.122	.054690	.172	.090042	.222	.129773
.023	.004619	.073	.025714	.123	.055346	.173	.090797	.223	.130605
.024	.004922	.074	.026236	.124	.056004	.174	.091555	.224	.131438
.025	.005231	.075	.026761	.125	.056664	.175	.092314	.225	.132273
.026	.005546	.076	.027290	.126	.057327	.176	.093074	.226	.133109
.027	.005867	.077	.027821	.127	.057991	.177	.093837	.227	.133946
.028	.006194	.078	.028356	.128	.058658	.178	.094601	.228	.134784
.029	.006527	.079	.028894	.129	.059328	.179	.095367	.229	.135624
.030	.006866	.080	.029435	.130	.059999	.180	.096135	.230	.136465
.031	.007209	.081	.029979	.131	.060673	.181	.096904	.231	.137307
.032	.007559	.082	.030526	.132	.061349	.182	.097675	.232	.138151
.033	.007913	.083	.031077	.133	.062027	.183	.098447	.233	.138996
.034	.008273	.084	.031630	.134	.062707	.184	.099221	.234	.139842
.035	.008638	.085	.032186	.135	.063389	.185	.099997	.235	.140689
.036	.009008	.086	.032746	.136	.064074	.186	.100774	.236	.141538
.037	.009383	.087	.033308	.137	.064761	.187	.101553	.237	.142388
.038	.009764	.088	.033873	.138	.065449	.188	.102334	.238	.143239
.039	.010148	.089	.034441	.139	.066140	.189	.103116	.239	.144091
.040	.010538	.090	.035012	.140	.066833	.190	.103900	.240	.144945
.041	.010932	.091	.035586	.141	.067528	.191	.104686	.241	.145800
.042	.011331	.092	.036162	.142	.068225	.192	.105472	.242	.146656
.043	.011734	.093	.036742	.143	.068924	.193	.106261	.243	.147513
.044	.012142	.094	.037324	.144	.069626	.194	.107051	.244	.148371
.045	.012555	.095	.037909	.145	.070329	.195	.107843	.245	.149231
.046	.012971	.096	.038497	.146	.071034	.196	.108636	.246	.150091
.047	.013393	.097	.039087	.147	.071741	.197	.109431	.247	.150953
.048	.013818	.098	.039681	.148	.072450	.198	.110227	.248	.151816
.049	.014248	.099	.040277	.149	.073162	.199	.111025	.249	.152681
.050	.014681	.100	.040875	.150	.073875	.200	.111824	.250	.153546

AREAS OF CIRCULAR SEGMENTS

TABLE II, FOR RATIOS OF RISE AND DIAMETER—CONCLUDED



$$\text{Area} = D^2 \times \text{Coefficient}$$

H/D	Coefficient	H/D	Coefficient	H/D	Coefficient	H/D	Coefficient	H/D	Coefficient
.251	.154413	.301	.199085	.351	.245935	.401	.294350	.451	.343778
.252	.155281	.302	.200003	.352	.246890	.402	.295330	.452	.344773
.253	.156149	.303	.200922	.353	.247845	.403	.296311	.453	.345768
.254	.157019	.304	.201841	.354	.248801	.404	.297292	.454	.346764
.255	.157891	.305	.202762	.355	.249758	.405	.298274	.455	.347760
.256	.158763	.306	.203683	.356	.250715	.406	.299256	.456	.348756
.257	.159636	.307	.204605	.357	.251673	.407	.300238	.457	.349752
.258	.160511	.308	.205528	.358	.252632	.408	.301221	.458	.350749
.259	.161386	.309	.206452	.359	.253591	.409	.302204	.459	.351745
.260	.162263	.310	.207376	.360	.254551	.410	.303187	.460	.352742
.261	.163141	.311	.208302	.361	.255511	.411	.304171	.461	.353739
.262	.164020	.312	.209228	.362	.256472	.412	.305156	.462	.354736
.263	.164900	.313	.210155	.363	.257433	.413	.306140	.463	.355733
.264	.165781	.314	.211083	.364	.258395	.414	.307125	.464	.356730
.265	.166663	.315	.212011	.365	.259358	.415	.308110	.465	.357728
.266	.167546	.316	.212941	.366	.260321	.416	.309096	.466	.358725
.267	.168431	.317	.213871	.367	.261285	.417	.310082	.467	.359723
.268	.169316	.318	.214802	.368	.262249	.418	.311068	.468	.360721
.269	.170202	.319	.215734	.369	.263214	.419	.312055	.469	.361719
.270	.171090	.320	.216666	.370	.264179	.420	.313042	.470	.362717
.271	.171978	.321	.217600	.371	.265145	.421	.314029	.471	.363715
.272	.172868	.322	.218534	.372	.266111	.422	.315017	.472	.364714
.273	.173758	.323	.219469	.373	.267078	.423	.316005	.473	.365712
.274	.174650	.324	.220404	.374	.268046	.424	.316993	.474	.366711
.275	.175542	.325	.221341	.375	.269014	.425	.317981	.475	.367710
.276	.176436	.326	.222278	.376	.269982	.426	.318970	.476	.368708
.277	.177330	.327	.223216	.377	.270951	.427	.319959	.477	.369707
.278	.178226	.328	.224154	.378	.271921	.428	.320949	.478	.370706
.279	.179122	.329	.225094	.379	.272891	.429	.321938	.479	.371705
.280	.180020	.330	.226034	.380	.273861	.430	.322928	.480	.372704
.281	.180918	.331	.226974	.381	.274832	.431	.323919	.481	.373704
.282	.181818	.332	.227916	.382	.275804	.432	.324909	.482	.374703
.283	.182718	.333	.228858	.383	.276776	.433	.325900	.483	.375702
.284	.183619	.334	.229801	.384	.277748	.434	.326891	.484	.376702
.285	.184522	.335	.230745	.385	.278721	.435	.327883	.485	.377701
.286	.185425	.336	.231689	.386	.279695	.436	.328874	.486	.378701
.287	.186329	.337	.232634	.387	.280669	.437	.329866	.487	.379701
.288	.187235	.338	.233580	.388	.281643	.438	.330858	.488	.380700
.289	.188141	.339	.234526	.389	.282618	.439	.331851	.489	.381700
.290	.189048	.340	.235473	.390	.283593	.440	.332843	.490	.382700
.291	.189956	.341	.236421	.391	.284569	.441	.333836	.491	.383700
.292	.190865	.342	.237369	.392	.285545	.442	.334829	.492	.384699
.293	.191774	.343	.238319	.393	.286521	.443	.335823	.493	.385699
.294	.192685	.344	.239268	.394	.287499	.444	.336816	.494	.386699
.295	.193597	.345	.240219	.395	.288476	.445	.337810	.495	.387699
.296	.194509	.346	.241170	.396	.289454	.446	.338804	.496	.388699
.297	.195423	.347	.242122	.397	.290432	.447	.339799	.497	.389699
.298	.196337	.348	.243074	.398	.291411	.448	.340793	.498	.390699
.299	.197252	.349	.244027	.399	.292390	.449	.341788	.499	.391699
.300	.198168	.350	.244980	.400	.293370	.450	.342783	.500	.392699

RELATIONS IN CIRCULAR SEGMENTS

Central Angle		A/R ²	C/R	H/R	H/C	Central Angle		A/R ²	C/R	H/R	H/C
a°	a _r	Area	Chord	Height	Height	a°	a _r	Area	Chord	Height	Height
Degree	Radians	Radius ²	Radius	Radius	Chord	Degree	Radians	Radius ²	Radius	Radius	Chord
1	.017453	(.6)44304	.017453	(.4)38077	.0021817	46	.802851	.0417559	.781462	.0794951	.101726
2	.034907	(.5)35442	.034905	(.3)15230	.0043634	47	.820305	.0444755	.797498	.0829399	.104000
3	.052360	(.4)11961	.052354	(.3)34268	.0065454	48	.837758	.0473066	.813473	.0864545	.106278
4	.069813	(.4)28348	.069799	(.3)60917	.0087275	49	.855211	.0502509	.829386	.0900387	.108561
5	.087266	(.4)55360	.087239	(.3)95178	.0109100	50	.872665	.0533101	.845237	.0936922	.110847
6	.104720	(.4)95646	.104672	(.2)13705	.0130929	51	.890118	.0564860	.861022	.0974147	.113138
7	.122173	(.3)15185	.122097	(.2)18652	.0152764	52	.907571	.0597802	.876742	.101206	.115434
8	.139626	(.3)22662	.139513	(.2)24359	.0174604	53	.925025	.0631945	.892396	.105066	.117734
9	.157080	(.3)32258	.156918	(.2)30827	.0196451	54	.942478	.0667304	.907981	.108994	.120039
10	.174533	(.3)44237	.174311	(.2)38053	.0218305	55	.959931	.0703896	.923497	.112989	.122349
11	.191986	(.3)58861	.191692	(.2)46038	.0240167	56	.977384	.0741734	.938943	.117052	.124664
12	.209440	(.3)76391	.209057	(.2)54781	.0262039	57	.994838	.0780836	.954318	.121183	.126984
13	.226893	(.3)97087	.226406	(.2)64281	.0283921	58	1.012291	.0821215	.969619	.125380	.129309
14	.244346	(.2)12121	.243739	(.2)74538	.0305813	59	1.029744	.0862885	.984847	.129644	.131639
15	.261799	(.2)14902	.261052	(.2)85551	.0327717	60	1.047198	.0905861	1.000000	.133975	.133975
16	.279253	(.2)18077	.278346	(.2)97319	.0349634	61	1.064651	.0950156	1.015077	.138371	.136316
17	.296706	(.2)21671	.295619	(.2)109841	.0371564	62	1.082104	.0995783	1.030076	.142833	.138662
18	.314159	(.2)25711	.312869	(.2)123117	.0393509	63	1.099557	.1042754	1.044997	.147360	.141015
19	.331613	(.2)30222	.330095	(.2)137144	.0415468	64	1.117011	.109108	1.059839	.151952	.143373
20	.349066	(.2)35229	.347296	(.2)151922	.0437443	65	1.134464	.114078	1.074599	.156609	.145737
21	.366519	(.2)40756	.364471	(.2)167451	.0459436	66	1.151917	.119186	1.089278	.161329	.148107
22	.383972	(.2)46829	.381618	(.2)183728	.0481445	67	1.169371	.124433	1.103874	.166114	.150483
23	.401426	(.2)53473	.398736	(.2)200753	.0503474	68	1.186824	.129820	1.118386	.170962	.152865
24	.418879	(.2)60712	.415823	(.2)218524	.0525521	69	1.204277	.135348	1.132812	.175874	.155254
25	.436332	(.2)68570	.432879	(.2)237040	.0547589	70	1.221730	.141019	1.147153	.180848	.157649
26	.453786	(.2)77072	.449902	(.2)256299	.0569678	71	1.239184	.146833	1.161406	.185885	.160051
27	.471239	(.2)86242	.466891	(.2)276301	.0591789	72	1.256637	.152790	1.175571	.190983	.162460
28	.488692	(.2)96103	.483844	(.2)297043	.0613923	73	1.274090	.158893	1.189646	.196143	.164875
29	.506145	.0106680	.500760	.0318524	.0636081	74	1.291544	.165141	1.203630	.201365	.167298
30	.523599	.0117994	.517638	.0340742	.0658263	75	1.308997	.171536	1.217523	.206647	.169727
31	.541052	.0130070	.534477	.0363695	.0680469	76	1.326450	.178077	1.231323	.211989	.172164
32	.558505	.0142931	.551275	.0387383	.0702704	77	1.343904	.184767	1.245029	.217392	.174608
33	.575959	.0156599	.568031	.0411803	.0724966	78	1.361357	.191605	1.258641	.222854	.177059
34	.593412	.0171095	.584743	.0436952	.0747254	79	1.378810	.198591	1.272156	.228375	.179518
35	.610865	.0186444	.601412	.0462830	.0769573	80	1.396263	.205728	1.285575	.233956	.181985
36	.628319	.0202666	.618034	.0489435	.0791922	81	1.413717	.213014	1.298896	.239594	.184460
37	.645772	.0219784	.634609	.0516763	.0814301	82	1.431171	.220451	1.312118	.245290	.186942
38	.663225	.0237818	.651136	.0544814	.0836713	83	1.448623	.228039	1.325240	.251044	.189433
39	.680678	.0256790	.667614	.0573585	.0859157	84	1.466077	.235777	1.338261	.256855	.191932
40	.698132	.0276721	.684040	.0603074	.0881635	85	1.483530	.243668	1.351180	.262723	.194439
41	.715585	.0297630	.700415	.0633278	.0904147	86	1.500983	.251710	1.363997	.268646	.196955
42	.733038	.0319539	.716736	.0664196	.0926696	87	1.518436	.259903	1.376709	.274626	.199480
43	.750492	.0342466	.733002	.0695824	.0949279	88	1.535890	.268249	1.389317	.280660	.202013
44	.767945	.0366433	.749213	.0728161	.0971901	89	1.553343	.276748	1.401819	.286750	.204555
45	.785398	.0391457	.765367	.0761205	.0994562	90	1.570796	.285398	1.414214	.292893	.207107

For angles a° less than 1°: Radians, a_r = .01745329 a°: A/R² = (.6)44304 a°³C/R = .0174531 a°: H/R = .000038077 a°²

H/C = .00218167 a°.

RELATIONS IN CIRCULAR SEGMENTS

Central Angle		A/R ²	C/R	H/R	H/C	Central Angle		A/R ²	C/R	H/R	H/C
a°	a _r	Area	Chord	Height	Height	a°	a _r	Area	Chord	Height	Height
Degree	Radians	Radius ²	Radius	Radius	Chord	Degree	Radians	Radius ²	Radius	Radius	Chord
91	1.588250	.294201	1.426501	.299091	.209667	136	2.373648	.839495	1.854368	.625393	.337254
92	1.605703	.303156	1.438680	.305342	.212237	137	2.391101	.854551	1.860835	.633499	.340438
93	1.623156	.312263	1.450749	.311645	.214817	138	2.408554	.869712	1.867161	.641632	.343641
94	1.640609	.321523	1.462707	.318002	.217406	139	2.426008	.884974	1.873344	.649793	.346862
95	1.658063	.330934	1.474555	.324410	.220005	140	2.443461	.900337	1.879385	.657980	.350104
96	1.675516	.340497	1.486290	.330869	.222614	141	2.460914	.915797	1.885283	.666193	.353365
97	1.692969	.350212	1.497911	.337380	.225234	142	2.478368	.931353	1.891037	.674432	.356647
98	1.710423	.360077	1.509419	.343941	.227863	143	2.495821	.947003	1.896647	.682695	.359948
99	1.727876	.370094	1.520812	.350552	.230503	144	2.513274	.962744	1.902113	.690983	.363271
100	1.745329	.380261	1.532089	.357212	.233154	145	2.530727	.978576	1.907434	.699294	.366615
101	1.762783	.390578	1.543249	.363922	.235815	146	2.548181	.994494	1.912610	.707628	.369981
102	1.780236	.401044	1.554292	.370680	.238488	147	2.565634	1.010498	1.917639	.715985	.373368
103	1.797689	.411660	1.565216	.377485	.241171	148	2.583087	1.026584	1.922523	.724363	.376777
104	1.815142	.422423	1.576022	.384339	.243866	149	2.600541	1.042751	1.927261	.732762	.380209
105	1.832596	.433335	1.586707	.391239	.246573	150	2.617994	1.058997	1.931852	.741181	.383664
106	1.850049	.444394	1.597271	.398185	.249291	151	2.635447	1.075319	1.936295	.749620	.387141
107	1.867502	.455599	1.607714	.405177	.252021	152	2.652900	1.091714	1.940591	.758078	.390643
108	1.884955	.466950	1.618034	.412215	.254763	153	2.670354	1.108182	1.944740	.766555	.394168
109	1.902409	.478445	1.628231	.419297	.257517	154	2.687807	1.124718	1.948740	.775049	.397718
110	1.919862	.490085	1.638304	.426424	.260284	155	2.705260	1.141321	1.952592	.783560	.401292
111	1.937315	.501868	1.648252	.433594	.263063	156	2.722714	1.157989	1.956295	.792088	.404892
112	1.954769	.513792	1.658075	.440807	.265855	157	2.740167	1.174718	1.959849	.800632	.408517
113	1.972222	.525859	1.667772	.448063	.268660	158	2.757620	1.191507	1.963254	.809191	.412168
114	1.989675	.538065	1.677341	.455361	.271478	159	2.775074	1.208353	1.966510	.817765	.415846
115	2.007129	.550410	1.686783	.462700	.274309	160	2.792527	1.225253	1.969616	.826352	.419550
116	2.024582	.562894	1.696096	.470081	.277155	161	2.809980	1.242206	1.972571	.834952	.423281
117	2.042035	.575514	1.705280	.477501	.280013	162	2.827433	1.259208	1.975377	.843566	.427040
118	2.059489	.588270	1.714335	.484962	.282886	163	2.844887	1.276258	1.978032	.852191	.430828
119	2.076942	.601161	1.723258	.492462	.285774	164	2.862340	1.293351	1.980536	.860827	.434643
120	2.094395	.614185	1.732051	.500000	.288675	165	2.879793	1.310487	1.982890	.869474	.438488
121	2.111848	.627341	1.740711	.507576	.291591	166	2.897247	1.327662	1.985092	.878131	.442363
122	2.129302	.640627	1.749239	.515190	.294523	167	2.914700	1.344874	1.987144	.886797	.446267
123	2.146755	.654042	1.757634	.522841	.297469	168	2.932153	1.362121	1.989044	.895472	.450202
124	2.164208	.667585	1.765895	.530528	.300430	169	2.949606	1.379399	1.990792	.904154	.454168
125	2.181662	.681255	1.774022	.538251	.303407	170	2.967060	1.396706	1.992389	.912844	.458166
126	2.199115	.695049	1.782013	.546010	.306400	171	2.984513	1.414039	1.993835	.921541	.462195
127	2.216568	.708966	1.789869	.553802	.309409	172	3.001966	1.431397	1.995128	.930244	.466258
128	2.234021	.723005	1.797588	.561629	.312435	173	3.019420	1.448775	1.996270	.938952	.470353
129	2.251475	.737164	1.805171	.569489	.315476	174	3.036873	1.466172	1.997259	.947664	.474482
130	2.268928	.751442	1.812616	.577382	.318535	175	3.054326	1.483585	1.998096	.956381	.478646
131	2.286381	.765836	1.819923	.585307	.321611	176	3.071779	1.501012	1.998782	.965101	.482844
132	2.303835	.780345	1.827091	.593263	.324704	177	3.089233	1.518448	1.999315	.973823	.487078
133	2.321288	.794967	1.834120	.601251	.327814	178	3.106686	1.535893	1.999695	.982548	.491349
134	2.338741	.809701	1.841010	.609269	.330943	179	3.124139	1.553343	1.999924	.991274	.495656
135	2.356194	.824544	1.847759	.617317	.334089	180	3.141593	1.570796	2.000000	1.000000	.500000

VALUES FOR COMBINATIONS OF π

$$\pi = 3.14159265359 \quad \log_{10} \pi = 0.4971498726$$

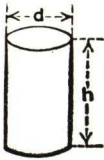
Combination	Values for n								
	1	2	3	4	5	6	7	8	9
$n\pi$	3.141593	6.283185	9.424773	12.566371	15.707963	18.849556	21.991149	25.132741	28.274334
$\frac{n\pi}{4}$	.785398	1.570796	2.356194	3.141593	3.926991	4.712389	5.497787	6.283185	7.068583
$\frac{n\pi}{6}$	.523599	1.047198	1.570796	2.094395	2.617994	3.141593	3.665191	4.188790	4.712389
$\frac{n\pi}{8}$	.392699	.785398	1.178097	1.570796	1.963495	2.356194	2.748894	3.141593	3.534292
$\frac{n\pi}{16}$	.196350	.392699	.589049	.785398	.981748	1.178097	1.374447	1.570796	1.767146
$\frac{n\pi}{32}$	.098175	1.96350	.294524	.392699	.490874	.589049	.687223	.785398	.883573
$\frac{n\pi}{64}$	.049087	.098175	.147262	.196350	.245437	.294524	.343612	.392699	.441786
$\frac{\pi}{n}$	3.141593	1.570796	1.047198	.785398	.628319	.523599	.448799	.392699	.349066
$\frac{n}{\pi}$	.318310	.636620	.954930	1.273240	1.591549	1.909859	2.228169	2.546479	2.864789
$\frac{\pi}{n 90^\circ}$	.034907	.017453	.011636	.008727	.006981	.005818	.004987	.004363	.003879
$\frac{n 90^\circ}{\pi}$	28.647890	57.295780	85.943669	114.59156	143.239450	171.88734	200.53523	229.18312	257.83101
πn	3.141593	9.869604	31.006277	97.409091	306.01968	961.38919	3020.2932	9488.5309	29809.100
$\frac{1}{\pi n}$	.318310	.101321	.032252	.010266	.003268	.001040	.000331	.000105	.000034
$\frac{1}{\sqrt{\pi n}}$	3.141593	1.772454	1.464592	1.331335	1.257274	1.210203	1.177664	1.153835	1.135635
$\frac{1}{\sqrt{n\pi}}$	.318310	.564190	.682784	.751126	.795371	.826307	.849139	.866675	.880564
$n\pi^2$	9.869604	19.739209	29.608813	39.478418	49.348022	59.217626	69.087231	79.956835	88.826439
$\frac{n}{\pi^2}$	.101321	.202642	.303964	.405285	.506606	.607927	.709248	.810569	.911891
$\sqrt{n\pi}$	1.772454	2.506628	3.069980	3.544908	3.963327	4.341608	4.689472	5.013257	5.317362
$\sqrt{\frac{n}{\pi}}$	.564190	.797885	.977205	1.128379	1.261566	1.381977	1.492705	1.595769	1.692569
$n\sqrt{\frac{n}{\pi}}$	1.772454	3.544908	5.317362	7.089815	8.862269	10.634723	12.407177	14.179631	15.952085
$\frac{n}{\sqrt{\pi}}$	.564190	1.128379	1.692569	2.256758	2.820948	3.385137	3.949327	4.513517	5.077706
$n\pi^3$	31.006277	62.012553	93.018830	124.02511	155.03138	186.03766	217.04394	248.05021	279.05649
$\frac{n}{\pi^3}$	.032252	.064503	.096755	.129006	.161258	.193509	.225761	.258012	.290264
$\sqrt[3]{n\pi}$	1.464592	1.845270	2.112307	2.324895	2.504417	2.661340	2.801664	2.929184	3.046474
$\sqrt[3]{\frac{n}{\pi}}$	.682784	.860254	.984745	1.083852	1.167544	1.240701	1.306189	1.365568	1.420248
$n\sqrt[3]{\frac{n}{\pi}}$	1.464592	2.929184	4.393776	5.858368	7.322960	8.787551	10.252143	11.716735	13.181327
$\frac{n}{\sqrt[3]{\pi}}$	.682784	1.365568	2.048352	2.7311363	3.4139203	4.096704	4.779489	5.462273	6.145057
$n\pi^4$	97.409091	194.81818	292.22727	389.63636	487.04545	584.45455	681.86364	779.27273	876.68182
$\frac{n}{\pi^4}$	.0102660	.0205320	.0307979	.0410639	.0513299	.061596	.071862	.082128	.092394
$\sqrt[4]{n\pi}$	1.331335	1.583233	1.752136	1.882793	1.990811	2.083653	2.165519	2.239030	2.305940
$\sqrt[4]{\frac{n}{\pi}}$	.751126	.893244	.988537	1.052252	1.123195	1.175575	1.221763	1.263238	1.300988

More accurate values frequently used:

$$\frac{\pi}{180} = 0.01745329252, \quad \log \frac{\pi}{180} = 8.2418773675 - 10, \quad \sqrt{\pi} = 1.772453851, \quad \log \sqrt{\pi} = .2485749363$$

$$\frac{180}{\pi} = 57.29577949, \quad \log \frac{180}{\pi} = 1.7581226325, \quad \sqrt[4]{\frac{1}{\pi}} = 0.5641895835, \quad \log \sqrt[4]{\frac{1}{\pi}} = 9.7514250637 - 10$$

SURFACES AND VOLUMES OF SOLIDS



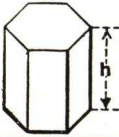
CYLINDER

$$\text{Convex Surface} = \pi dh$$

$$\text{Total Surface} = \pi dh + \frac{\pi d^2}{2}$$

$$\text{Volume} = \frac{\pi}{4} d^2 h$$

Volume Cylinder, right or oblique = area of section at right angles to sides $\times$ length of side.

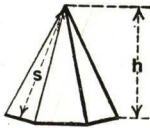


PRISM

$$\text{Lateral Surface} = h \times \text{Base Perimeter}$$

$$\text{Total Surface} = \text{Lateral Surface} + (2 \times \text{Base Area})$$

$$\text{Volume} = h \times \text{Base Area}$$



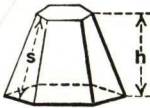
PYRAMID

$$\text{Lateral Surface} = \frac{s}{2} \times \text{Base Perimeter}$$

$$\text{Total Surface} = \text{Lateral Surface} + \text{Base Area}$$

$$\text{Volume} = \frac{h}{3} \times \text{Base Area}$$

$$\text{Center of Gravity} = \frac{h}{4}, \text{ above base}$$



FRUSTUM OF PYRAMID

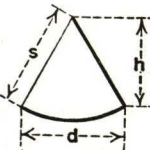
$$\text{Lateral Surface} = s(\text{Top} + \text{Base Perimeters}) \div 2$$

If a = top area and A = base area,

$$\text{Total Surface} = \text{Lateral Surface} + (a + A)$$

$$\text{Volume} = h(a + A + \sqrt{aA}) \div 3$$

$$\text{Center of Gravity above base} = \frac{h}{4} \left(\frac{3a + A + 2\sqrt{aA}}{a + A + \sqrt{aA}} \right)$$



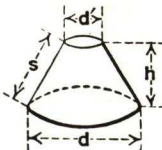
CONE

$$\text{Convex Surface} = \frac{\pi}{2} ds = \frac{\pi d}{4} \sqrt{d^2 + 4h^2}$$

$$\text{Total Surface} = \text{Convex Surface} + \frac{\pi d^2}{4}$$

$$\text{Volume} = \frac{\pi}{12} d^2 h = \frac{\pi}{24} d^2 \sqrt{4s^2 - d^2}$$

$$\text{Center of Gravity above base} = \frac{h}{4}$$



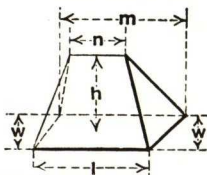
FRUSTUM OF CONE

$$\text{Convex Surface} = \frac{\pi s}{2} (d + d') = \frac{\pi}{4} (d + d') \sqrt{4h^2 + (d - d')^2}$$

$$\text{Total Surface} = \frac{\pi s}{2} (d + d') + \frac{\pi}{4} (d^2 + d'^2)$$

$$\text{Volume} = \frac{\pi h}{12} (d^2 + dd' + d'^2)$$

$$\text{Center of Gravity above base} = \frac{h(d^2 + 2dd' + 3d'^2)}{4(d^2 + dd' + d'^2)}$$

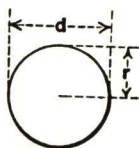


WEDGE

$$\text{Surface} = \text{Sum of surfaces of bounding planes}$$

$$\text{Volume} = \frac{wh}{6} (l + m + n)$$

SURFACES AND VOLUMES OF SOLIDS



SPHERE

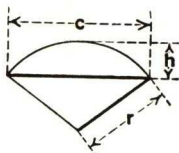
$$\text{Surface} = \pi d^2 = 4\pi r^2$$

$$\text{Volume} = \frac{\pi d^3}{6} = \frac{4}{3} \pi r^3$$

Side of an equal cube = diameter of sphere $\times 0.806$

Length of an equal cylinder = diameter of sphere $\times 0.6667$

Center of Gravity of Half Sphere = $\frac{3}{8}r$ above spherical center

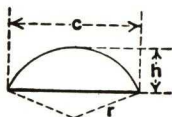


SPHERICAL SECTOR

$$\text{Total Surface} = \frac{\pi r}{2} (4h + c)$$

$$\text{Volume} = \frac{2}{3}\pi r^2 h = \frac{2}{3}\pi r^2 \left(r - \sqrt{r^2 - \frac{c^2}{4}} \right)$$

$$\text{Center of Gravity above center of sphere} = \frac{3}{8} \left(r - \frac{h}{2} \right)$$



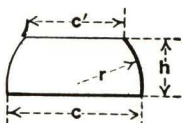
SPHERICAL SEGMENT

$$\text{Spherical Surface} = 2\pi r h = \pi(c^2 + 4h^2) \div 4$$

$$\text{Total Surface} = \text{Spherical Surface} + (\pi c^2 \div 4)$$

$$\text{Volume} = \pi h^2(3r - h) \div 3 = \pi h(3c^2 + 4h^2) \div 24$$

$$\text{Center of gravity above base of segment} = h(4r - h) \div 4(3r - h)$$

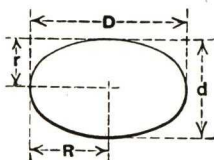


SPHERICAL ZONE

$$\text{Convex Surface} = 2\pi r h$$

$$\text{Total Surface} = 2\pi r h + \frac{\pi}{4} (c^2 + c'^2)$$

$$\text{Volume} = \frac{\pi h}{24} (3c^2 + 3c'^2 + 4h^2)$$



ELLIPSOID (I. Revolution about transverse axis)

$$\text{Surface} = 2\pi r \left[r + R \left(\frac{\sin^{-1}e}{e} \right) \right]$$

$$\text{Volume} = \frac{4}{3} \pi R r^2$$

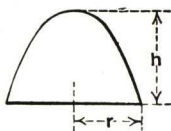
$\frac{\sin^{-1}e}{e}$
= Angle, in
radians,
whose sine = e

ELLIPSOID (II. Revolution about conjugate axis)

$$\text{Surface} = \pi \left[2R^2 + \frac{2.303r^2}{e} \log \left(\frac{1+e}{1-e} \right) \right]$$

$$\text{Volume} = \frac{4}{3} \pi R^2 r \quad \text{Where } e = \frac{\sqrt{R^2 - r^2}}{R}$$

Use common, or base 10, log.



PARABOLOID

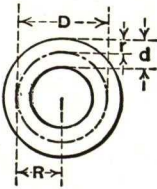
$$\text{Convex Surface} = \frac{\pi r}{6h^2} \left[(r^2 + 4h^2)^{3/2} - r^3 \right]$$

$$\text{Total Surface} = \text{Convex Surface} + \pi r^2$$

$$\text{Volume} = \frac{\pi r^2 h}{2}$$

$$\text{Center of Gravity} = \frac{h}{3} \text{ above base}$$

SURFACES AND VOLUMES OF SOLIDS



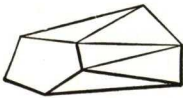
CIRCULAR RING (TORUS)

D and R = Mean Diameter and Mean Radius, respectively, of Ring

d and r = Mean Diameter and Mean Radius, respectively, of Section

$$\text{Surface} = \pi^2 Dd = 4\pi^2 Rr$$

$$\text{Volume} = 2\pi^2 Rr^2 = \frac{\pi^2}{4} Dd^2$$



PRISMOID

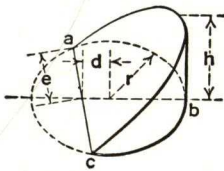
End faces are in parallel planes.

$$\text{Volume} = \frac{l}{6} (A + A' + 4M), \text{ where}$$

l = perpendicular distance between ends

A, A' = areas of ends

M = area of mid section, parallel to ends



UNGULAS FROM RIGHT CIRCULAR CYLINDER

(As formed by cutting plane oblique to base)

I. Base, abc, less than semicircle;

Convex Surface

$$= h[2re - (d \times \text{length arc abc})] \div (r - d)$$

$$\text{Volume} = h \left[\frac{2}{3}e^3 - (d \times \text{area base abc}) \right] \div (r - d)$$

II. Base, abc = semicircle;

Convex Surface

$$= 2rh \quad \text{Volume} = \frac{2}{3}r^2h$$

III. Base, abc, greater than semicircle (figure)

Convex Surface

$$= h[2re + (d \times \text{length arc abc})] \div (r + d)$$

$$\text{Volume} = h \left[\frac{2}{3}e^3 + (d \times \text{area base abc}) \right] \div (r + d)$$

IV. Base, abc, = circle, oblique plane touching circumference.

Convex Surface

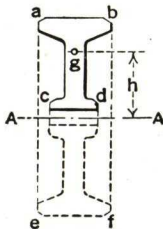
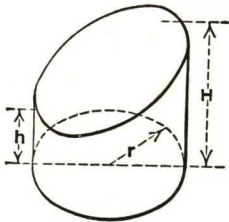
$$= \pi rh \quad \text{Volume} = \frac{1}{2}\pi r^2h$$

V. Base, abc, = circle, oblique plane entirely above (figure)

Convex Surface

$$= 2\pi r \times \frac{1}{2}(h, \text{minimum} + H, \text{maximum})$$

$$\text{Volume} = \pi r^2 \times \frac{1}{2}(h, \text{minimum} + H, \text{maximum})$$



ANY SOLID OF REVOLUTION

Let abcd represent the generating section about axis A-A of solid abef.

Let g at distance h from A-A be the center of gravity of abcd.

Let α° be the angular amount of generating revolution.

Then

Total Surface of solid abef

$$= (2\pi h\alpha \div 360) \times \text{perimeter abcd}$$

$$\text{Volume of solid abef} = (2\pi h\alpha \div 360) \times \text{area abcd}$$

$$\text{For complete revolution } (2\pi h\alpha \div 360) = 2\pi h$$

WEIGHTS OF SHEETS AND PLATES

STEEL, WROUGHT IRON, COPPER AND BRASS

BIRMINGHAM WIRE GAGE (B. W. G.)

Number of Gage	Thickness in Inches	Weight per Square Foot			
		Steel	Iron	Copper	Brass
4/0s	.454	18.5232	18.16	20.5662	19.4312
3/0s	.425	17.3400	17.00	19.2525	18.1900
2/0s	.380	15.5040	15.20	17.2140	16.2640
1/0	.340	13.8720	13.60	15.4020	14.5520
1	.300	12.2400	12.00	13.5900	12.8400
2	.284	11.5872	11.36	12.8652	12.1552
3	.259	10.5672	10.36	11.7327	11.0852
4	.238	9.7104	9.52	10.7814	10.1864
5	.220	8.9760	8.80	9.9660	9.4160
6	.203	8.2824	8.12	9.1959	8.6884
7	.180	7.3440	7.20	8.1540	7.7040
8	.165	6.7320	6.60	7.4745	7.0620
9	.148	6.0384	5.92	6.7044	6.3344
10	.134	5.4672	5.36	6.0702	5.7352
11	.120	4.8960	4.80	5.4360	5.1360
12	.109	4.4472	4.36	4.9377	4.6652
13	.095	3.8760	3.80	4.3035	4.0660
14	.083	3.3864	3.32	3.7599	3.5524
15	.072	2.9376	2.88	3.2616	3.0816
16	.065	2.6520	2.60	2.9445	2.7820
17	.058	2.3664	2.32	2.6274	2.4824
18	.049	1.9992	1.96	2.2197	2.0972
19	.042	1.7136	1.68	1.9026	1.7976
20	.035	1.4280	1.40	1.5855	1.4980
21	.032	1.3056	1.28	1.4496	1.3696
22	.028	1.1424	1.12	1.2684	1.1984
23	.025	1.0200	1.00	1.1325	1.0700
24	.022	.8976	.88	.9966	.9416
25	.020	.8160	.80	.9060	.8560
26	.018	.7344	.72	.8154	.7704
27	.016	.6528	.64	.7248	.6848
28	.014	.5712	.56	.6342	.5992
29	.013	.5304	.52	.5889	.5564
30	.012	.4896	.48	.5436	.5136
31	.010	.4080	.40	.4530	.4280
32	.009	.3672	.36	.4077	.3852
33	.008	.3264	.32	.3624	.3424
34	.007	.2856	.28	.3171	.2996
35	.005	.2040	.20	.2265	.2140
36	.004	.1632	.16	.1812	.1712
Specific Gravities.....		7.85	7.70	8.72	8.24
Weight of a Cubic Foot..		489.6	480.0	543.6	513.6
" " " Inch..		.2833	.2778	.3146	.2972

This gage is standard for PLATES when a number gage is used without further specification. PLATES, when of steel (Uniform Classification of September 20, 1933) are 0.250 inches thick and thicker in widths $6\frac{1}{4}$ to 48 inches, and .1875 inches thick or thicker for greater widths.

WEIGHTS OF SHEETS AND PLATES

STEEL, WROUGHT IRON, COPPER AND BRASS

AMERICAN OR BROWNE & SHARPE GAGE

Number of Gage	Thickness in Inches	Weight per Square Foot			
		Steel	Iron	Copper	Brass
4/0s	.460000	18.7680	18.4000	20.8380	19.6880
3/0s	.409642	16.7134	16.3857	18.5568	17.5327
2/0s	.364796	14.8837	14.5918	16.5253	15.6133
1/0	.324861	13.2543	12.9944	14.7162	13.9041
1	.289297	11.8033	11.5719	13.1052	12.3819
2	.257627	10.5112	10.3051	11.6705	11.0264
3	.229423	9.3605	9.1769	10.3929	9.8193
4	.204307	8.3357	8.1723	9.2551	8.7443
5	.181940	7.4232	7.2776	8.2419	7.7870
6	.162023	6.6105	6.4809	7.3396	6.9346
7	.144285	5.8868	5.7714	6.5361	6.1754
8	.128490	5.2424	5.1396	5.8206	5.4994
9	.114423	4.6685	4.5769	5.1834	4.8973
10	.101897	4.1574	4.0759	4.6159	4.3612
11	.090742	3.7023	3.6297	4.1106	3.8838
12	.080808	3.2970	3.2323	3.6606	3.4586
13	.071962	2.9360	2.8785	3.2599	3.0800
14	.064084	2.6146	2.5634	2.9030	2.7428
15	.057068	2.3284	2.2827	2.5852	2.4425
16	.050821	2.0735	2.0328	2.3022	2.1751
17	.045257	1.8465	1.8103	2.0501	1.9370
18	.040303	1.6444	1.6121	1.8257	1.7250
19	.035890	1.4643	1.4356	1.6258	1.5361
20	.031961	1.3040	1.2784	1.4478	1.3679
21	.028462	1.1612	1.1385	1.2893	1.2182
22	.025346	1.0341	1.0138	1.1482	1.0848
23	.022572	.92094	.90288	1.0225	.96608
24	.020101	.82012	.80404	.91058	.86032
25	.017900	.73032	.71600	.81087	.76612
26	.015941	.65039	.63764	.72213	.68227
27	.014195	.57916	.56780	.64303	.60755
28	.012641	.51575	.50564	.57264	.54103
29	.011257	.45929	.45028	.50994	.48180
30	.010025	.40902	.40100	.45413	.42907
31	.008928	.36426	.35712	.40444	.38212
32	.007950	.32436	.31800	.36014	.34026
33	.007080	.28886	.28320	.32072	.30302
34	.006305	.25724	.25220	.28562	.26985
35	.005615	.22909	.22460	.25436	.24032
36	.005000	.20400	.20000	.22650	.21400
37	.004453	.18168	.17812	.20172	.19059
38	.003965	.16177	.15860	.17961	.16970
39	.003531	.14406	.14124	.15995	.15113
40	.003144	.12828	.12576	.14242	.13456

This is not a standard gage for steel sheets or plates, but may be specified, if desired.
 Normally used for copper wire and for non-ferrous sheet material.

THICKNESS OF SHEETS AND PLATES

STEEL, WROUGHT IRON, COPPER AND BRASS

UNITED STATES STANDARD GAGE

As this is purely a weight gage, the thickness varies with the material.

Number of Gage	Weight in Pounds per Square Foot	Thickness, Inches			
		Steel	Iron (Base of System)	Copper	Brass
7/0s	20.00	.4902	.500000	.4415	.4673
6/0s	18.75	.4596	.468750	.4139	.4381
5/0s	17.50	.4289	.437500	.3863	.4089
4/0s	16.25	.3983	.406250	.3587	.3797
3/0s	15.00	.3676	.375000	.3311	.3505
2/0s	13.75	.3370	.343750	.3035	.3213
1/0	12.50	.3064	.312500	.2759	.2921
1	11.25	.2757	.281250	.2483	.2629
2	10.625	.2604	.265625	.2345	.2482
3	10.00	.2451	.250000	.2208	.2336
4	9.375	.2298	.234375	.2070	.2190
5	8.750	.2145	.218750	.1932	.2044
6	8.125	.1991	.203125	.1794	.1898
7	7.500	.1838	.187500	.1656	.1752
8	6.875	.1685	.171875	.1518	.1606
9	6.250	.1532	.15625	.1380	.1460
10	5.625	.1379	.140625	.1242	.1314
11	5.000	.1225	.125000	.1104	.1168
12	4.375	.1072	.109375	.09658	.1022
13	3.750	.09191	.093750	.08278	.08762
14	3.125	.07659	.078125	.06898	.07301
15	2.8125	.06893	.0703125	.06209	.06571
16	2.500	.06127	.0625000	.05519	.05841
17	2.250	.05515	.0562500	.04967	.05257
18	2.000	.04902	.0500000	.04415	.04673
19	1.750	.04289	.0437500	.03863	.04089
20	1.500	.03676	.0375000	.03311	.03505
21	1.375	.03370	.0343750	.03035	.03213
22	1.250	.03064	.0312500	.02759	.02921
23	1.125	.02757	.0281250	.02483	.02629
24	1.000	.02451	.0250000	.02208	.02336
25	.8750	.02145	.0218750	.01932	.02044
26	.7500	.01838	.0187500	.01656	.01752
27	.6875	.01685	.0171875	.01518	.01606
28	.6250	.01532	.0156250	.01380	.01460
29	.5625	.01379	.0140625	.01242	.01314
30	.5000	.01225	.0125000	.01104	.01168
31	.4375	.01072	.0109375	.009658	.01022
32	.40625	.009957	.0101563	.008968	.009492
33	.3750	.009191	.0093750	.008278	.008762
34	.34375	.008425	.0085938	.007588	.008032
35	.3125	.007659	.0078125	.006898	.007301
36	.28125	.006893	.0070313	.006209	.006571
37	.265625	.006510	.0066406	.005864	.006206
38	.250	.006127	.00625	.005519	.005841
39	.234375	.005744	.0058594	.005174	.005476
40	.21875	.005362	.0054688	.004829	.005111

This gage is standard for SHEETS when a number gage is used without further specification.

WIRE AND SHEET METAL GAGES

IN DECIMALS OF AN INCH

Name of Gage	United States Standard Gage*		Birmingham (or Stubbs) Iron Wire Gage	New Birmingham Standard Sheet and Hoop Gage	American or Browne & Sharpe Wire Gage	United States Steel Wire formerly Washburn & Moent	British Imperial or English Legal Standard Wire Gage	American Screw Co. Screw Wire Gage	Name of Gage
Principal Use	Uncoated Steel Sheets and Light Plates		B.W.G.	B.G.	B. & S.				Principal Use
Gage No.	Weight, Pounds per Sq. Ft.	Thickness, Inches	Strips, Bands, Hoops and Wire	Iron and Steel Sheets and Hoops	Non-Ferrous Sheets and Wire	Steel Wire except Music Wire	S. W. G.	Wire	Gage No.
Thickness or Diameter, Inches									
7-0s	20.00	.4902	-----	.6666	-----	.4900	.500	-----	7-0s
6-0s	18.75	.4596	-----	.6250	.580000	.4615	.464	-----	6-0s
5-0s	17.50	.4289	.500	.5883	.516500	.4305	.432	-----	5-0s
4-0s	16.25	.3983	.454	.5416	.460000	.3938	.400	-----	4-0s
3-0s	15.00	.3676	.425	.5000	.409642	.3625	.372	.0315	3-0s
2-0s	13.75	.3370	.380	.4452	.364796	.3310	.348	.0447	2-0s
1-0	12.50	.3064	.340	.3964	.324861	.3065	.324	.0578	1-0
1	11.25	.2757	.300	.3532	.289297	.2830	.300	.0710	1
2	10.625	.2604	.284	.3147	.257627	.2625	.276	.0842	2
3	10.00	.2451	.259	.2804	.229423	.2437	.252	.0973	3
4	9.375	.2298	.238	.2500	.204307	.2253	.232	.1105	4
5	8.750	.2145	.220	.2225	.181940	.2070	.212	.1236	5
6	8.125	.1991	.203	.1981	.162023	.1920	.192	.1368	6
7	7.500	.1838	.180	.1764	.144285	.1770	.176	.1500	7
8	6.875	.1685	.165	.1570	.128490	.1620	.160	.1631	8
9	6.250	.1532	.148	.1398	.114423	.1483	.144	.1763	9
10	5.625	.1379	.134	.1250	.101897	.1350	.128	.1894	10
11	5.000	.1225	.120	.1113	.090742	.1205	.116	.2026	11
12	4.375	.1072	.109	.0991	.080808	.1055	.104	.2158	12
13	3.750	.0919	.095	.0882	.071962	.0915	.092	.2289	13
14	3.125	.0766	.083	.0785	.064084	.0800	.080	.2421	14
15	2.8125	.0689	.072	.0699	.057068	.0720	.072	.2552	15
16	2.500	.0613	.065	.0625	.050821	.0625	.064	.2684	16
17	2.250	.0551	.058	.0556	.045257	.0540	.056	.2816	17
18	2.000	.0490	.049	.0495	.040303	.0475	.048	.2947	18
19	1.750	.0429	.042	.0440	.035890	.0410	.040	.3079	19
20	1.500	.0368	.035	.0392	.031961	.0348	.036	.3210	20
21	1.375	.0337	.032	.0349	.028462	.03175	.032	.3342	21
22	1.250	.0306	.028	.03125	.025346	.0286	.028	.3474	22
23	1.125	.0276	.025	.02782	.022572	.0258	.024	.3605	23
24	1.000	.0245	.022	.02476	.020101	.0230	.022	.3737	24
25	.875	.0214	.020	.02204	.017900	.0204	.020	.3868	25
26	.750	.0184	.018	.01961	.015941	.0181	.018	.4000	26
27	.6875	.0169	.016	.01745	.014195	.0173	.0164	.4132	27
28	.625	.0153	.014	.015625	.012641	.0162	.0148	.4263	28
29	.5625	.0138	.013	.0139	.011257	.0150	.0136	.4395	29
30	.5000	.0123	.012	.0123	.010025	.0140	.0124	.4526	30
31	.4375	.0107	.010	.0110	.008928	.0132	.0116	.4658	31
32	.4062	.0100	.009	.0098	.007950	.0128	.0108	.4790	32
33	.3750	.0092	.008	.0087	.007080	.0118	.0100	.4921	33
34	.3438	.0084	.007	.0077	.006305	.0104	.0092	.5053	34
35	.3125	.0077	.005	.0069	.005615	.0095	.0084	.5184	35
36	.2812	.0069	.004	.0061	.005000	.0090	.0076	.5316	36
37	.2656	.0065	-----	.0054	.004453	.0085	.0068	.5448	37
38	.2500	.0061	-----	.0048	.003965	.0080	.0060	.5579	38
39	.2344	.0057	-----	.0043	.003531	.0075	.0052	.5711	39
40	.2188	.0054	-----	.00386	.003144	.0070	.0048	.5842	40

*U. S. Standard Gage is officially a weight gage (in ounces per sq. ft.) based on wrought iron at 480 lb. per cu. ft. The values tabulated above give the thickness of steel (at 489.6 lb. per cu. ft.) that will approximate the respective weights. The other gages are officially thickness gages.

†Also American Steel & Wire Co. and John A. Roebling Co. gages.

PRINCIPAL WIRE GAGES

COMBINED TABLES OF SIZES

Values rounded to 4 significant figures, except column headed "Diameter, inches."

Diameter			Wire Gage Number					Cross Section			
Mils	Mm.	Ins.	B. & S.	W. & M.	B. W. G.	S. W. G.	Met-ric	Square Inches	Square Mils	Circular Mils	Square Mm.
500	12.70	.500	-----	-----	-----	7/0	-----	.1963	196 300	250 000	126.7
490	12.45	.490	-----	7/0	-----	-----	-----	.1886	188 600	240 100	121.7
464	11.79	.464	-----	-----	-----	6/0	-----	.1691	169 100	215 300	109.1
461.5	11.70	.4615	-----	6/0	-----	-----	-----	.1673	167 300	213 000	107.9
460	11.68	.460	4/0	-----	-----	-----	-----	.1662	166 200	211 600	107.2
454	11.53	.454	-----	-----	4/0	-----	-----	.1619	161 900	206 100	104.4
432	10.97	.432	-----	-----	-----	5/0	-----	.1466	146 600	186 600	94.56
430.5	10.93	.4305	-----	5/0	-----	-----	-----	.1456	145 600	185 300	93.91
425	10.80	.425	-----	-----	3/0	-----	-----	.1419	141 900	180 600	91.52
409.6	10.40	.410	3/0	-----	-----	-----	-----	.1318	131 800	167 800	85.03
400	10.16	.400	-----	-----	-----	4/0	-----	.1257	125 700	160 000	81.07
393.8	10.00	.3938	-----	4/0	-----	-----	-----	.1218	121 800	155 100	78.58
393.7	10.0	.3937	-----	-----	-----	-----	100	.1217	121 700	155 000	78.54
380	9.652	.380	-----	-----	2/0	-----	-----	.1134	113 400	144 400	73.17
372	9.449	.372	-----	-----	-----	3/0	-----	.1087	108 700	138 400	70.12
364.8	9.266	.365	2/0	-----	-----	-----	-----	.1045	104 500	133 100	67.43
362.5	9.208	.3625	-----	3/0	-----	-----	-----	.1032	103 200	131 400	66.58
354.3	9.0	.354	-----	-----	-----	-----	90	.09861	98 610	125 500	63.62
348	8.839	.348	-----	-----	-----	2/0	-----	.09511	95 110	121 100	61.36
340	8.636	.340	-----	-----	0	-----	-----	.09079	90 790	115 600	58.58
331	8.407	.331	-----	2/0	-----	-----	-----	.08605	86 050	109 600	55.52
324.9	8.251	.325	0	-----	-----	-----	-----	.08289	82 890	105 500	53.48
324	8.230	.324	-----	-----	-----	0	-----	.08245	82 450	105 000	53.19
315	8.0	.315	-----	-----	-----	-----	80	.07791	77 910	99 200	50.27
306.5	7.785	.3065	-----	0	-----	-----	-----	.07378	73 780	93 940	47.60
300	7.620	.300	-----	-----	1	1	-----	.07069	70 690	90 000	45.60
289.3	7.348	.289	1	-----	-----	-----	-----	.06573	65 730	83 690	42.41
284	7.214	.284	-----	-----	2	-----	-----	.06335	63 350	80 660	40.87
283	7.188	.283	-----	1	-----	-----	-----	.06290	62 900	80 090	40.58
276	7.010	.276	-----	-----	-----	2	-----	.05983	59 830	76 180	38.60
275.6	7.0	.276	-----	-----	-----	-----	70	.05965	59 650	75 950	38.48
262.5	6.668	.2625	-----	2	-----	-----	-----	.05412	54 120	68 910	34.92
259	6.579	.259	-----	-----	3	-----	-----	.05269	52 690	67 080	33.99
257.6	6.544	.258	2	-----	-----	-----	-----	.05213	52 130	66 370	33.63
252	6.401	.252	-----	-----	-----	3	-----	.04988	49 880	63 500	32.18
243.7	6.190	.2437	-----	3	-----	-----	-----	.04664	46 640	59 390	30.09
238	6.045	.238	-----	-----	4	-----	-----	.04449	44 490	56 640	28.70
236.2	6.0	.236	-----	-----	-----	-----	60	.04383	43 830	55 800	28.27
232	5.893	.232	-----	-----	-----	4	-----	.04227	42 270	53 820	27.27
229.4	5.827	.229	3	-----	-----	-----	-----	.04134	41 340	52 630	26.67
225.3	5.723	.2253	-----	4	-----	-----	-----	.03987	39 870	50 760	25.72
220	5.588	.220	-----	-----	5	-----	-----	.03801	38 010	48 400	24.52
212	5.385	.212	-----	-----	-----	5	-----	.03530	35 300	44 940	22.77
207	5.258	.207	-----	5	-----	-----	-----	.03365	33 650	42 850	21.71
204.3	5.189	.204	4	-----	-----	-----	-----	.03278	32 780	41 740	21.15

1 Mil = 0.001 inch; 1 Square Mil = .000,001 sq. in.; 1 Circular Mil = Area of Wire 1 Mil in Diameter = .000,0007854 sq. in.; B. & S. = Browne & Sharpe Gage; W. & M. = Washburn & Moen, or United States Steel Wire, or American Steel & Wire Co., or John A. Roebling Sons Co. Gage; B. W. G. = Birmingham Wire, or Stubbs Iron Wire Gage; S. W. G. = British Standard Wire Gage; Metric = Millimeter Diameter Gage.

PRINCIPAL WIRE GAGES

COMBINED TABLES OF SIZES

Values rounded to 4 significant figures, except column headed "Diameter, inches."

Diameter			Wire Gage Number					Cross Section			
Mils	Mm.	Ins.	B. & S.	W. & M.	B. W. G.	S. W. G.	Metric	Square Inches	Square Mils	Circular Mils	Square Mm.
203	5.156	.203	-----	-----	6	-----	-----	.032 37	32 370	41 210	20.88
196.8	5.0	.197	-----	-----	-----	-----	50	.030 43	30 430	38 750	19.63
192	4.877	.192	-----	6	-----	6	-----	.028 95	28 950	36 860	18.68
181.9	4.621	.182	5	-----	-----	-----	-----	.026 00	26 000	33 100	16.77
180	4.572	.180	-----	-----	7	-----	-----	.025 45	25 450	32 400	16.42
177.2	4.5	.177	-----	-----	-----	-----	45	.024 65	24 650	31 390	15.90
177	4.496	.177	-----	7	-----	-----	-----	.024 61	24 610	31 330	15.87
176	4.470	.176	-----	-----	-----	7	-----	.024 33	24 330	30 980	15.70
165	4.191	.165	-----	-----	8	-----	-----	.021 38	21 380	27 220	13.80
162	4.115	.162	6	8	-----	-----	-----	.020 62	20 620	26 250	13.30
160	4.064	.160	-----	-----	-----	8	-----	.020 11	20 110	25 600	12.97
157.5	4.0	.157	-----	-----	-----	-----	40	.019 48	19 480	24 810	12.57
148.3	3.767	.1483	-----	9	-----	-----	-----	.017 27	17 270	21 990	11.14
148	3.759	.148	-----	-----	9	-----	-----	.017 20	17 200	21 900	11.10
144.3	3.665	.144	7	-----	-----	-----	-----	.016 35	16 350	20 820	10.55
144	3.658	.144	-----	-----	-----	9	-----	.016 29	16 290	20 740	10.51
137.8	3.5	.138	-----	-----	-----	-----	35	.014 91	14 910	18 990	9.621
135	3.429	.135	-----	10	-----	-----	-----	.014 31	14 310	18 220	9.235
134	3.404	.134	-----	-----	10	-----	-----	.014 10	14 100	17 960	9.098
128.5	3.264	.128	8	-----	-----	-----	-----	.012 97	12 970	16 510	8.366
128	3.251	.128	-----	-----	-----	10	-----	.012 87	12 870	16 380	8.302
120.5	3.061	.1205	-----	11	-----	-----	-----	.011 40	11 400	14 520	7.358
120	3.048	.120	-----	-----	11	-----	-----	.011 31	11 310	14 400	7.297
118.1	3.0	.118	-----	-----	-----	-----	30	.010 96	10 960	13 950	7.069
116	2.946	.116	-----	-----	-----	11	-----	.010 57	10 570	13 460	6.818
114.4	2.906	.114	9	-----	-----	-----	-----	.010 28	10 280	13 090	6.634
109	2.769	.109	-----	-----	12	-----	-----	.009 331	9331	11 880	6.020
105.5	2.680	.1055	-----	12	-----	-----	-----	.008 742	8742	11 130	5.640
104	2.642	.104	-----	-----	-----	12	-----	.008 495	8495	10 820	5.481
101.9	2.588	.102	10	-----	-----	-----	-----	.008 155	8155	10 380	5.261
98.42	2.5	.098	-----	-----	-----	-----	25	.007 609	7609	9687	4.909
95	2.413	.095	-----	-----	13	-----	-----	.007 088	7088	9025	4.573
92	2.337	.092	-----	-----	-----	13	-----	.006 648	6648	8464	4.289
91.5	2.324	.0915	-----	13	-----	-----	-----	.006 576	6576	8372	4.242
90.74	2.305	.091	11	-----	-----	-----	-----	.006 467	6467	8234	4.172
83	2.108	.083	-----	-----	14	-----	-----	.005 411	5411	6889	3.491
80.81	2.053	.081	12	-----	-----	-----	-----	.005 129	5129	6530	3.309
80	2.032	.080	-----	14	-----	14	-----	.005 027	5027	6400	3.243
78.74	2.0	.079	-----	-----	-----	-----	20	.004 869	4869	6200	3.142
72	1.829	.072	-----	15	15	15	-----	.004 072	4072	5184	2.627
71.96	1.828	.072	13	-----	-----	-----	-----	.004 067	4067	5178	2.624
70.87	1.8	.071	-----	-----	-----	-----	18	.003 944	3944	5022	2.545
65	1.651	.065	-----	-----	16	-----	-----	.003 318	3318	4225	2.141
64.08	1.628	.064	14	-----	-----	-----	-----	.003 225	3225	4107	2.081
64	1.626	.064	-----	-----	-----	16	-----	.003 217	3217	4096	2.075

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PRINCIPAL WIRE GAGES

COMBINED TABLES OF SIZES

Values rounded to 4 significant figures, except column headed "Diameter, inches."

Diameter			Wire Gage Number					Cross Section			
Mils	Mm.	Ins.	B. & S.	W. & M.	B. W. G.	S. W. G.	Metric	Square Inches	Square Mils	Circular Mils	Square Mm.
62.99	1.6	.063	-----	-----	-----	-----	16	.003 116	3116	3968	2.011
62.5	1.588	.0625	-----	16	-----	-----	-----	.003 068	3068	3906	1.979
58	1.473	.058	-----	-----	17	-----	-----	.002 642	2642	3364	1.705
57.07	1.450	.057	15	-----	-----	-----	-----	.002 558	2558	3257	1.650
56	1.422	.056	-----	-----	-----	17	-----	.002 463	2463	3136	1.589
55.12	1.4	.055	-----	-----	-----	-----	14	.002 386	2386	3038	1.539
54	1.372	.054	-----	17	-----	-----	-----	.002 290	2290	2916	1.478
50.82	1.291	.051	16	-----	-----	-----	-----	.002 028	2028	2583	1.309
49	1.245	.049	-----	-----	18	-----	-----	.001 886	1886	2401	1.217
48	1.219	.048	-----	-----	-----	18	-----	.001 810	1810	2304	1.167
47.5	1.207	.0475	-----	18	-----	-----	-----	.001 772	1772	2256	1.143
47.24	1.2	.047	-----	-----	-----	-----	12	.001 753	1753	2232	1.131
45.26	1.150	.045	17	-----	-----	-----	-----	.001 609	1609	2048	1.038
42	1.067	.042	-----	-----	19	-----	-----	.001 385	1385	1764	.8938
41	1.041	.041	-----	19	-----	-----	-----	.001 320	1320	1681	.8518
40.3	1.024	.040	18	-----	-----	-----	-----	.001 276	1276	1624	.8231
40	1.016	.040	-----	-----	-----	19	-----	.001 257	1257	1600	.8107
39.37	1.0	.039	-----	-----	-----	-----	10	.001 217	1217	1550	.7854
36	.9144	.036	-----	-----	-----	20	-----	.001 018	1018	1296	.6567
35.89	.9116	.036	19	-----	-----	-----	-----	.001 012	1012	1288	.6527
35.43	.90	.035	-----	-----	-----	-----	9	.039861	986.1	1255	.6362
35	.8890	.035	-----	-----	20	-----	-----	.039621	962.1	1225	.6207
34.8	.8839	.0348	-----	20	-----	-----	-----	.039511	951.1	1211	.6136
32	.8128	.032	-----	-----	21	21	-----	.038042	804.2	1024	.5189
31.96	.8118	.032	20	-----	-----	-----	-----	.038023	802.3	1022	.5176
31.7	.8052	.0317	-----	21	-----	-----	-----	.037892	789.2	1005	.5092
31.5	.80	.031	-----	-----	-----	-----	8	.037791	779.1	992	.5027
28.6	.7264	.0286	-----	22	-----	-----	-----	.036424	642.4	818	.4145
28.46	.7229	.0285	21	-----	-----	-----	-----	.036363	636.3	810.1	.4105
28	.7112	.028	-----	-----	22	22	-----	.036158	615.8	784	.3973
27.56	.70	.0276	-----	-----	-----	-----	7	.035965	596.5	759.5	.3848
25.8	.6553	.0258	-----	23	-----	-----	-----	.035228	522.8	665.6	.3373
25.35	.6438	.0253	22	-----	-----	-----	-----	.035046	504.6	642.4	.3255
25	.6350	.025	-----	-----	23	-----	-----	.034909	490.9	625	.3167
24	.6096	.024	-----	-----	-----	23	-----	.034524	452.4	576	.2919
23.62	.60	.0236	-----	-----	-----	-----	6	.034383	438.3	558	.2827
23	.5842	.023	-----	24	-----	-----	-----	.034155	415.5	529	.2675
22.57	.5733	.0226	23	-----	-----	-----	-----	.034001	400.1	509.5	.2582
22	.5588	.022	-----	-----	24	24	-----	.033801	380.1	484	.2452
20.4	.5182	.0204	-----	25	-----	-----	-----	.033269	326.9	416.2	.2109
20.1	.5106	.0201	24	-----	-----	-----	-----	.033173	317.3	404	.2047
20	.5080	.020	-----	-----	25	25	-----	.033142	314.2	400	.2027
19.68	.50	.0197	-----	-----	-----	-----	5	.033043	304.3	387.5	.1963
18.1	.4597	.0181	-----	26	-----	-----	-----	.032573	257.3	327.6	.1660
18	.4572	.018	-----	-----	26	26	-----	.032545	254.5	324	.1642

.03 = .000 For example, .039861 = .0009861

1 Mil = 0.001 inch; 1 Square Mil = .000,001 sq. in.; 1 Circular Mil = Area of Wire 1 Mil in Diameter = .000,0007854 sq. in.; B. & S. = Browne & Sharpe Gage; W. & M. = Washburn & Moen, or United States Steel Wire, or American Steel & Wire Co., or John A. Roebling Sons Co. Gage; B. W. G. = Birmingham Wire, or Stubs Iron Wire Gage; S. W. G. = British Standard Wire Gage; Metric = Millimeter Diameter Gage.

PRINCIPAL WIRE GAGES

COMBINED TABLES OF SIZES

Values rounded to 4 significant figures, except column headed "Diameter, inches."

Diameter			Wire Gage Number					Cross Section			
Mils	Mm.	Ins.	B. & S.	W. & M.	B. W. G.	S. W. G.	Metric	Square Inches	Square Mils	Circular Mils	Square Mm.
17.9	.4547	.0179	25	-----	-----	-----	-----	.032517	251.7	320.4	.1624
17.72	.45	.0177	-----	-----	-----	-----	4.5	.032465	246.5	313.9	.1590
17.3	.4394	.0173	-----	27	-----	-----	-----	.032351	235.1	299.3	.1517
16.4	.4166	.0164	-----	-----	-----	27	-----	.032112	211.2	269	.1363
16.2	.4115	.0162	-----	28	-----	-----	-----	.032061	206.1	262.4	.1330
16	.4064	.016	-----	-----	27	-----	-----	.032011	201.1	256	.1297
15.94	.4049	.0159	26	-----	-----	-----	-----	.031996	199.6	254.1	.1288
15.75	.40	.0157	-----	-----	-----	-----	4	.031948	194.8	248	.1257
15	.3810	.015	-----	29	-----	-----	-----	.031767	176.7	225	.1140
14.8	.3759	.0148	-----	-----	-----	28	-----	.031720	172.0	219	.1110
14.2	.3606	.0142	27	-----	-----	-----	-----	.031583	158.3	201.5	.1021
14	.3556	.0140	-----	30	28	-----	-----	.031539	153.9	196	.099 32
13.78	.35	.0138	-----	-----	-----	-----	3.5	.031491	149.1	189.9	.096 21
13.6	.3454	.0136	-----	-----	-----	29	-----	.031453	145.3	185	.093 72
13.2	.3353	.0132	-----	31	-----	-----	-----	.031368	136.8	174.2	.088 29
13	.3302	.0130	-----	-----	29	-----	-----	.031327	132.7	169	.085 63
12.8	.3251	.0128	-----	32	-----	-----	-----	.031287	128.7	163.8	.083 02
12.64	.3211	.0126	28	-----	-----	-----	-----	.031255	125.5	159.8	.080 98
12.4	.3150	.0124	-----	-----	-----	30	-----	.031208	120.8	153.8	.077 91
12	.3048	.0120	-----	-----	30	-----	-----	.031131	113.1	144	.072 97
11.81	.30	.0118	-----	-----	-----	-----	3	.031096	109.6	139.5	.070 69
11.8	.2997	.0118	-----	33	-----	-----	-----	.031094	109.4	139.2	.070 55
11.6	.2946	.0116	-----	-----	-----	31	-----	.031057	105.7	134.6	.068 18
11.26	.2859	.0113	29	-----	-----	-----	-----	.030954	99.54	126.7	.064 22
10.8	.2743	.0108	-----	-----	-----	32	-----	.030916	91.61	116.6	.059 10
10.4	.2642	.0104	-----	34	-----	-----	-----	.030849	84.95	108.2	.054 81
10.03	.2546	.0100	30	-----	-----	-----	-----	.030789	78.94	100.5	.050 93
10	.2540	.0100	-----	-----	31	33	-----	.030785	78.54	100	.050 67
9.842	.25	.0098	-----	-----	-----	-----	2.5	.030760	76.09	96.87	.049 09
9.5	.2413	.0095	-----	35	-----	-----	-----	.030788	70.88	90.25	.045 73
9.2	.2337	.0092	-----	-----	-----	34	-----	.030648	66.48	84.64	.042 89
9	.2286	.0090	-----	36	32	-----	-----	.030632	63.62	81	.041 04
8.928	.2268	.0089	31	-----	-----	-----	-----	.030620	62.60	79.7	.040 39
8.5	.2159	.0085	-----	37	-----	-----	-----	.030575	56.75	72.25	.036 61
8.4	.2134	.0084	-----	-----	-----	35	-----	.030542	55.42	70.56	.035 75
8	.2032	.0080	-----	38	33	-----	-----	.030507	50.27	64	.032 43
7.95	.2019	.0080	32	-----	-----	-----	-----	.030496	49.64	63.21	.032 03
7.874	.20	.0079	-----	-----	-----	-----	2	.030486	48.69	62.00	.031 42
7.6	.1930	.0076	-----	-----	-----	36	-----	.030453	45.36	57.76	.029 27
7.5	.1905	.0075	-----	39	-----	-----	-----	.030418	44.18	56.25	.028 50
7.087	.18	.0071	-----	-----	-----	-----	1.8	.030394	39.44	50.22	.025 45
7.08	.1798	.0071	33	-----	-----	-----	-----	.030397	39.37	50.13	.025 40
7	.1778	.0070	-----	40	34	-----	-----	.030384	38.48	49	.024 83
6.8	.1727	.0068	-----	-----	-----	37	-----	.030363	36.32	46.24	.023 43
6.6	.1676	.0066	-----	41	-----	-----	-----	.030342	34.21	43.56	.022 07

.03 = .000 For example, .032517 = .0002517

1 Mil = 0.001 inch; 1 Square Mil = .000,001 sq. in.; 1 Circular Mil = Area of Wire 1 Mil in Diameter = .000,0007854 sq. in.; B. & S. = Browne & Sharpe Gage; W. & M. = Washburn & Moen, or United States Steel Wire, or American Steel & Wire Co., or John A. Roebling Sons Co. Gage; B. W. G. = Birmingham Wire, or Stubbs Iron Wire Gage; S. W. G. = British Standard Wire Gage; Metric = Millimeter Diameter Gage.

PRINCIPAL WIRE GAGES

COMBINED TABLES OF SIZES

Values rounded to 4 significant figures, except column headed "Diameter, inches."

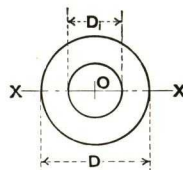
Diameter			Wire Gage Number					Cross Section			
Mils	Mm.	ins.	B. & S.	W. & M.	B. W. G.	S. W. G.	Metric	Square Inches	Square Mils	Circular Mils	Square Mm.
6.305	.1601	.0063	34	-----	-----	-----	-----	.043122	31.22	39.75	.020 14
6.299	.16	.0063	-----	-----	-----	-----	1.6	.043116	31.16	39.68	.020 11
6.2	.1575	.0062	-----	42	-----	-----	-----	.043019	30.19	38.44	.019 48
6	.1524	.0060	-----	43	-----	38	-----	.042827	28.27	36	.018 24
5.906	.15	.0059	-----	-----	-----	-----	1.5	.042739	27.39	34.87	.017 67
5.8	.1473	.0058	-----	44	-----	-----	-----	.042642	26.42	33.64	.017 05
5.615	.1426	.0056	35	-----	-----	-----	-----	.042476	24.76	31.52	.015 97
5.512	.14	.0055	-----	-----	-----	-----	1.4	.042386	23.86	30.38	.015 39
5.5	.1397	.0055	-----	45	-----	-----	-----	.042376	23.76	30.25	.015 33
5.2	.1321	.0052	-----	46	-----	39	-----	.042124	21.24	27.04	.013 70
5	.1270	.0050	36	47	35	-----	-----	.041963	19.63	25	.012 67
4.8	.1219	.0048	-----	48	-----	40	-----	.041810	18.10	23.04	.011 67
4.724	.12	.0047	-----	-----	-----	-----	1.2	.041753	17.53	22.32	.011 31
4.6	.1168	.0046	-----	49	-----	-----	-----	.041662	16.62	21.16	.010 72
4.453	.1131	.0045	37	-----	-----	-----	-----	.041557	15.57	19.83	.010 05
4.4	.1118	.0044	-----	50	-----	41	-----	.041521	15.21	19.36	.009 810
4	.1016	.0040	-----	-----	36	42	-----	.041257	12.57	16	.008 107
3.965	.1007	.0040	38	-----	-----	-----	-----	.041235	12.35	15.72	.007 967
3.937	.10	.0039	-----	-----	-----	-----	1	.041217	12.17	15.50	.007 854
3.6	.091 44	.0036	-----	-----	-----	43	-----	.041018	10.18	12.96	.006 567
3.531	.089 69	.0035	39	-----	-----	-----	-----	.049793	9.793	12.47	.006 318
3.2	.081 28	.0032	-----	-----	-----	44	-----	.048042	8.042	10.24	.005 189
3.145	.079 87	.0031	40	-----	-----	-----	-----	.047766	7.766	9.888	.005 010
2.800	.071 13	.0028	41	-----	-----	-----	-----	.046159	6.159	7.842	.003 973
2.8	.071 12	.0028	-----	-----	-----	45	-----	.046158	6.158	7.84	.003 973
2.494	.063 34	.0025	42	-----	-----	-----	-----	.044884	4.884	6.219	.003 151
2.4	.060 96	.0024	-----	-----	-----	46	-----	.044524	4.524	5.76	.002 919
2.221	.056 41	.0022	43	-----	-----	-----	-----	.043873	3.873	4.932	.002 499
2	.050 80	.0020	-----	-----	-----	47	-----	.043142	3.142	4	.002 027
1.978	.050 23	.0020	44	-----	-----	-----	-----	.043072	3.072	3.911	.001 982
1.969	.05	.0020	-----	-----	-----	-----	0.5	.043044	3.044	3.875	.001 963
1.761	.044 73	.0018	45	-----	-----	-----	-----	.042436	2.436	3.102	.001 572
1.6	.040 64	.0016	-----	-----	-----	48	-----	.042011	2.011	2.560	.001 297
1.568	.039 84	.0016	46	-----	-----	-----	-----	.041932	1.932	2.460	.001 246
1.397	.035 47	.0014	47	-----	-----	-----	-----	.041532	1.532	1.951	.001 9884
1.243	.031 59	.0012	48	-----	-----	-----	-----	.041215	1.215	1.547	.001 7838
1.2	.030 48	.0012	-----	-----	-----	49	-----	.041131	1.131	1.44	.001 7297
1.107	.028 13	.0011	49	-----	-----	-----	-----	.049635	.9635	1.227	.001 6216
1	.025 40	.0010	-----	-----	-----	50	-----	.047854	.7854	1	.001 5067
.9863	.025 05	.0010	50	-----	-----	-----	-----	.047641	.7641	.9728	.001 4929

.04 = .0000 For example, .043122 = .00003122

1 Mil = 0.001 inch; 1 Square Mil = .000,001 sq. in.; 1 Circular Mil = Area of Wire 1 Mil in Diameter = .000,0007854 sq. in.; B. & S. = Browne & Sharpe Gage; W. & M. = Washburn & Moen, or United States Steel Wire, or American Steel & Wire Co., or John A. Roebling Sons Co. Gage; B. W. G. = Birmingham Wire, or Stubbs Iron Wire Gage; S. W. G. = British Standard Wire Gage; Metric = Millimeter Diameter Gage.

SOLID AND HOLLOW SHAFTING

WITH
WEIGHT AND TORSIONAL STRENGTH REDUCTIONS
OF SOLID SHAFT BY HOLE,
PER CENT



See Footnotes on pages 285—287.

D_i , In.	DIAMETER OF AXIAL HOLE, Inches, D_i .														1st line = % strength reduction from solid, D^* 2nd line = % weight reduction from solid, $D^\dagger$	
$GI_p = \frac{EI_x}{1.30}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
$S_p = 2S_x$																
2	6.25															
1.812(7)	25.00															
1.5708																
3	1.23	19.75														
9.175(7)	11.11	44.44														
5.3015																
4	0.39	6.25	31.64													
2.900(8)	6.25	25.00	56.25													
12.566																
5	0.16	2.56	12.96	40.96												
7.080(8)	4.00	16.00	36.00	64.00												
24.544																
6	0.08	1.23	6.25	19.75	48.23											
1.468(9)	2.78	11.11	25.00	44.44	69.44											
42.412																
7	0.04	0.67	3.37	10.66	26.03	53.98										
2.720(9)	2.04	8.16	18.37	32.65	51.02	73.47										
67.348																
8	0.02	0.39	1.98	6.25	15.26	31.64	58.62									
4.640(9)	1.56	6.25	14.06	25.00	39.06	56.25	76.56									
100.53																
9	0.02	0.24	1.23	3.90	9.53	19.75	36.60	62.43								
7.432(9)	1.23	4.94	11.11	19.75	30.86	44.44	60.49	79.01								
143.14																
10	0.01	0.16	0.81	2.56	6.25	12.96	24.01	40.96	65.61							
11.33 (9)	1.00	4.00	9.00	16.00	25.00	36.00	49.00	64.00	81.00							
196.35																
11				1.75	4.27	8.85	16.40	27.98	44.81	68.30						
16.59 (9)				13.22	20.66	29.75	40.50	52.89	66.94	82.64						
261.34																
12				1.23	3.01	6.25	11.58	19.75	31.64	48.23	70.61					
23.49 (9)				11.11	17.36	25.00	34.03	44.44	56.25	69.44	84.03					
339.29																
13				0.90	2.19	4.54	8.41	14.34	22.97	35.01	51.26	72.60				
32.35 (9)				9.47	14.79	21.30	28.99	37.87	47.93	59.17	71.60	85.21				
431.38																
14				0.67	1.63	3.37	6.25	10.66	17.08	26.03	38.11	53.98	74.35			
43.52 (9)				8.16	12.76	18.37	25.00	32.65	41.33	51.02	61.73	73.47	86.22			
538.78																
15				0.51	1.23	2.56	4.74	8.09	12.96	19.75	28.92	40.96	56.42	75.88		
57.35 (9)				7.11	11.11	16.00	21.78	28.44	36.00	44.44	53.78	64.00	75.11	87.11		
662.68																
16				0.39	0.95	1.98	3.66	6.25	10.01	15.26	22.34	31.64	43.58	58.62	77.25	
74.24 (9)				6.25	9.77	14.06	19.14	25.00	31.64	39.06	47.27	56.25	66.02	76.56	87.89	
804.25																
17				0.31	0.75	1.55	2.87	4.90	7.86	11.97	17.53	24.83	34.20	46.00	60.61	
94.61 (9)				5.54	8.65	12.46	16.96	22.15	28.03	34.60	41.87	49.83	58.48	67.82	77.85	
964.67																
18				0.24	0.60	1.23	2.29	3.90	6.25	9.53	13.95	19.75	27.21	36.60	48.23	
118.9 (9)				4.94	7.72	11.11	15.12	19.75	25.00	30.86	37.35	44.44	52.16	60.49	69.44	
1145.1																

NOTES ON SHAFTING DESIGN AND THE USE OF THE TABLES.

(9) represents 1,000,000,000 times. For example, 1.812(7) = 18,120,000

SOLID SHAFT OF DIAMETER, D inches.

STIFFNESS, Inch²-Pounds.

TORSIONAL STIFFNESS = (GI_p) .

BENDING STIFFNESS = $(EI_x) = 1.30 (GI_p)$.

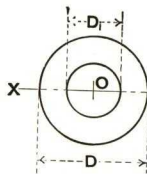
STRENGTH COEFFICIENT (SECTION MODULUS), In.³ Pole O for torsion; axis X-X for bending.

Torsional Coefficient = S_p . Bending Coefficient = S_x . $S_p = 2 S_x$.

HOLLOW SHAFT (H) of Outside Diameter D and Inside Diameter D_i .

STIFFNESS, $(GI_p)_H = (GI_p)_D - (GI_p)_{D_i}$. STRENGTH $(S_p)_H = 2(GI_p)_H / D$. (Not $(S_p)_D - (S_p)_{D_i}$.)

*Decrease in Strength = $(D_i / D)^4 \times 100\%$. †Decrease in Weight = $(D_i / D)^2 \times 100\%$ Based on solid D .



SOLID AND HOLLOW SHAFTING

WITH

WEIGHT AND TORSIONAL STRENGTH REDUCTIONS OF SOLID SHAFT BY HOLE, PER CENT

See Footnotes on pages 285-287.

D, In.	DIAMETER OF AXIAL HOLE, Inches, D _i											1st line = % strength reduction from solid, D. 2d line = % weight reduction from solid, D.	
$G I_p = \frac{E I_x}{1.30}$ $S_p = 2S_x$	4	5	6	7	8	9	10	11	12	13	14	15	
19 147.6(9) 1346.8	0.20 4.43	0.48 6.93	0.99 9.97	1.84 13.57	3.14 17.73	5.03 22.44	7.67 27.70	11.23 33.52	15.91 39.89	21.92 46.81	29.48 54.29	38.85 62.33	
20 181.2(9) 1570.8	0.16 4.00	0.39 6.25	0.81 9.00	1.50 12.25	2.56 16.00	4.10 20.25	6.25 25.00	9.15 30.25	12.96 36.00	17.85 42.25	24.01 49.00	31.64 56.25	
21 220.3(9) 1818.4	0.13 3.63	0.32 5.67	0.67 8.16	1.23 11.11	2.11 14.51	3.37 18.37	5.14 22.68	7.53 27.44	10.66 32.65	14.69 38.32	19.75 44.44	26.03 51.02	
22 265.4(9) 2090.7	0.11 3.31	0.27 5.17	0.55 7.44	1.02 10.12	1.75 13.22	2.80 16.74	4.27 20.66	6.25 25.00	8.85 29.75	12.19 34.92	16.40 40.50	21.61 46.49	
23 317.0(9) 2389.0	0.09 3.02	0.22 4.73	0.46 6.81	0.86 9.26	1.46 12.10	2.34 15.31	3.57 18.90	5.23 22.87	7.41 27.22	10.21 31.95	13.73 37.05	18.09 42.53	
24 375.8(9) 2714.3	0.08 2.78	0.19 4.34	0.39 6.25	0.72 8.51	1.23 11.11	1.98 14.06	3.01 17.36	4.41 21.01	6.25 25.00	8.61 29.34	11.58 34.03	15.26 39.06	
25 442.5(9) 3068.0	0.07 2.56	0.16 4.00	0.33 5.76	0.61 7.84	1.05 10.24	1.68 12.96	2.56 16.00	3.75 19.36	5.31 23.04	7.31 27.04	9.83 31.36	12.96 36.00	
26 517.7(9) 3451.0	0.06 2.37	0.14 3.70	0.28 5.33	0.53 7.25	0.90 9.47	1.44 11.98	2.19 14.79	3.20 17.90	4.54 21.30	6.25 25.00	8.41 28.99	11.08 33.28	
27 602.0(9) 3864.7	0.05 2.19	0.12 3.43	0.24 4.94	0.45 6.72	0.77 8.78	1.23 11.11	1.88 13.72	2.75 16.60	3.90 19.75	5.37 23.18	7.23 26.89	9.53 30.86	
28 696.3(9) 4310.3	0.04 2.04	0.10 3.19	0.21 4.59	0.39 6.25	0.67 8.16	1.07 10.33	1.63 12.76	2.38 15.43	3.37 18.37	4.65 21.56	6.25 25.00	8.24 28.70	
29 801.2(9) 4788.8	0.04 1.90	0.09 2.97	0.18 4.28	0.34 5.83	0.58 7.61	0.93 9.63	1.41 11.89	2.07 14.39	2.93 17.12	4.04 20.10	5.43 23.31	7.16 26.75	
30 917.6(9) 5301.5	0.03 1.78	0.08 2.78	0.16 4.00	0.30 5.44	0.51 7.11	0.81 9.00	1.23 11.11	1.81 13.44	2.56 16.00	3.53 18.78	4.74 21.78	6.25 25.00	
31 1046 (9) 5849.5	0.03 1.66	0.07 2.60	0.14 3.75	0.26 5.10	0.44 6.66	0.71 8.43	1.08 10.41	1.59 12.59	2.25 14.98	3.09 17.59	4.16 20.40	5.48 23.41	
32 1188 (9) 6434.0	0.02 1.56	0.06 2.44	0.12 3.52	0.23 4.79	0.39 6.25	0.63 7.91	0.95 9.77	1.40 11.82	1.98 14.06	2.72 16.50	3.66 19.14	4.83 21.97	
33 1343 (9) 7056.2	0.02 1.47	0.05 2.30	0.11 3.31	0.20 4.50	0.35 5.88	0.55 7.44	0.84 9.18	1.23 11.11	1.75 13.22	2.41 15.52	3.24 18.00	4.27 20.66	
34 1514 (9) 7717.3	0.02 1.38	0.05 2.16	0.10 3.11	0.18 4.24	0.31 5.54	0.49 7.01	0.75 8.65	1.10 10.47	1.55 12.46	2.14 14.62	2.87 16.96	3.79 19.46	
35 1700 (9) 8418.5	0.02 1.31	0.04 2.04	0.09 2.94	0.16 4.00	0.27 5.22	0.44 6.61	0.67 8.16	0.98 9.88	1.38 11.76	1.90 13.80	2.56 16.00	3.37 18.37	

In the tables above, per cent decrease in strength or weight may be found on the line corresponding to the solid shaft diameter and in the column corresponding to the hole diameter.

Tension Modulus of Elasticity = $E = 30,000,000$ lb. per sq. in. Poisson's Ratio = $(1/m) = .300$.

Shearing " " Rigidity = $G = \frac{1}{2} E / (1 + 1/m) = 30,000,000 \cdot 2.60 = 11,538,500$ lb. per sq. in.

MOMENTS APPLIED AT SECTION, In.-Lb. BENDING = M_B . TORSION = M_T .

DISTORTION BETWEEN TWO SECTIONS. TORSION; ϕ = Radians Twist. BENDING;

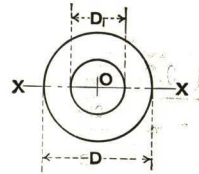
y = Inches Deflection.

DISTORTION AT SECTION. TORSION; $d\phi/dx$ = Radians twist per inch. BENDING; d^2y/dx^2

= Curvature, Inch⁻¹.

$M_T = (G I_p) (d\phi/dx)$; $(d\phi/dx) = M_T / (G I_p)$. $M_B = (E I_x) (d^2y/dx^2)$; $(d^2y/dx^2) = M_B / (E I_x)$.

SOLID AND HOLLOW SHAFTING WITH WEIGHT AND TORSIONAL STRENGTH REDUCTIONS OF SOLID SHAFT BY HOLE, PER CENT



See Footnotes on pages 285-287.

D, In.	DIAMETER OF AXIAL HOLE, Inches, D ₁													1st line = % strength reduction from solid, D. 2nd line = % weight reduction from solid, D.	
$G I_p = \frac{E I_x}{1.30}$	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
$S_p = 2S_x$															
17	78.47														
94.61 (9)	88.58														
964.67															
18	62.43	79.56													
118.9 (9)	79.01	89.20													
1145.1															
19	50.29	64.09	80.55												
147.6 (9)	70.91	80.06	89.75												
1346.8															
20	40.96	52.20	65.61	81.45											
181.2 (9)	64.00	72.25	81.00	90.25											
1570.8															
21	33.70	42.95	53.98	67.01	82.27										
220.3 (9)	58.04	65.53	73.47	81.86	90.70										
1818.4															
22	27.98	35.65	44.81	55.63	68.30	83.02									
265.4 (9)	52.89	59.71	66.94	74.59	82.64	91.16									
2090.7															
23	23.42	29.85	37.51	46.57	57.18	69.50	83.71								
317.0 (9)	48.39	54.63	61.25	68.24	75.61	83.36	91.49								
2389.0															
24	19.75	25.17	31.64	39.28	48.23	58.62	70.61	84.35							
375.8 (9)	44.44	50.17	56.25	62.67	69.44	76.56	84.03	91.84							
2714.3															
25	16.78	21.38	26.87	33.36	40.96	49.79	59.97	71.64	84.93						
442.5 (9)	40.96	46.24	51.84	57.76	64.00	70.56	77.44	84.64	92.16						
3068.0															
26	14.34	18.28	22.97	28.52	35.01	42.56	51.26	61.24	72.60	85.48					
517.7 (9)	37.87	42.75	47.93	53.40	59.17	65.24	71.60	78.25	85.21	92.46					
3451.0															
27	12.33	15.72	19.75	24.52	30.11	36.60	44.08	52.66	62.43	73.50	85.99				
602.0 (9)	35.12	39.64	44.44	49.52	54.87	60.49	66.39	72.57	79.01	85.73	92.73				
3864.7															
28	10.66	13.59	17.08	21.20	26.03	31.64	38.11	45.53	53.98	63.55	74.35	86.46			
696.3 (9)	32.65	36.86	41.33	46.05	51.02	56.25	61.73	67.47	73.47	79.72	86.22	92.98			
4310.3															
29	9.27	11.81	14.84	18.43	22.62	27.50	33.12	39.57	46.91	55.23	64.61	75.14	86.90		
801.2 (9)	30.44	34.36	38.53	42.93	47.56	52.44	57.55	62.90	68.49	74.32	80.38	86.68	93.22		
4788.8															
30	8.09	10.31	12.96	16.09	19.75	24.01	28.92	34.55	40.96	48.23	56.42	65.61	75.88	87.32	
917.6 (9)	28.44	32.11	36.00	40.11	44.44	49.00	53.78	58.78	64.00	69.44	75.11	81.00	87.11	93.44	
5301.5															
31	7.10	9.04	11.37	14.11	17.33	21.06	25.37	30.30	35.93	42.30	49.48	57.55	66.56	76.59	
1046 (9)	26.64	30.07	33.71	37.57	41.62	45.89	50.36	55.05	59.94	65.04	70.34	75.86	81.58	87.51	
5849.5															
32	6.25	7.97	10.01	12.43	15.26	18.55	22.34	26.69	31.64	37.25	43.58	50.68	58.62	67.45	
1188 (9)	25.00	28.22	31.64	35.25	39.06	43.07	47.27	51.66	56.25	61.04	66.02	71.19	76.56	82.13	
6434.0															
33	5.53	7.04	8.85	10.99	13.49	16.40	19.75	23.60	27.98	32.94	38.53	44.81	51.83	59.64	
1343 (9)	23.51	26.54	29.75	33.15	36.73	40.50	44.44	48.58	52.89	57.39	62.08	66.94	71.99	77.23	
7056.2															
34	4.90	6.25	7.86	9.75	11.97	14.55	17.53	20.94	24.83	29.23	34.20	39.77	46.00	52.93	
1514 (9)	22.15	25.00	28.03	31.23	34.60	38.15	41.87	45.76	49.83	54.07	58.48	63.06	67.82	72.75	
7717.3															
35	4.37	5.57	7.00	8.68	10.66	12.96	15.61	18.65	22.11	26.03	30.45	35.41	40.96	47.13	
1700 (9)	20.90	23.59	26.45	29.47	32.65	36.00	39.51	43.18	47.02	51.02	55.18	59.51	64.00	68.65	
8418.5															

STRESSES AT SECTION. Lb. per sq. in.

BENDING = f_B . TORSION = f_T .

$M_T = f_T S_p$; $f_T = M_T / S_p$.

$M_B = f_B S_x$; $f_B = M_B / S_x$.

COMBINED STRESSES AT SECTION. Lb. per sq. in. SHEAR = f_s . DIRECT (Tension or

Compression) = f_t .

$2 f_s = \sqrt{4 f_T^2 + f_B^2}$ $2 f_t = f_B + 2 f_s$.

1.00 to 2.50"
(0.100 to 0.250")
(10.0 to 25.0")

REVOLUTIONS PER MINUTE FOR ASSIGNED SURFACE SPEEDS

Diam- eter D	Circumference		S=Surface Speeds, Feet per Minute; Diameters in Inches									
	πD	$\frac{\pi D}{12}$	20	25	30	35		45				
	In.	Ft.	40	50	60	70	80	90	100	125	150	
					120	140	160	180	200	250	300	
1.000	3.1416	.2618	152.79	190.99	229.18	267.38	305.58	343.77	381.97	477.46	572.96	
1.010	3.1730	.2644	151.28	189.10	226.91	264.73	302.55	340.37	378.19	472.74	567.28	
1.020	3.2044	.2670	149.79	187.24	224.69	262.14	299.59	337.03	374.48	468.10	561.72	
1.030	3.2358	.2697	148.34	185.42	222.51	259.59	296.68	333.76	370.85	463.56	556.27	
1.040	3.2673	.2723	146.91	183.64	220.37	257.10	293.82	330.55	367.28	459.10	550.92	
1.050	3.2987	.2749	145.51	181.89	218.27	254.65	291.03	327.40	363.78	454.73	545.67	
1.060	3.3301	.2775	144.14	180.18	216.21	252.25	288.28	324.32	360.35	450.44	540.53	
1.070	3.3615	.2801	142.79	178.49	214.19	249.89	285.59	321.28	356.98	446.23	535.47	
1.080	3.3929	.2827	141.47	176.84	212.21	247.57	282.94	318.31	353.68	442.10	530.52	
1.090	3.4243	.2854	140.17	175.22	210.26	245.30	280.35	315.39	350.43	438.04	525.65	
1.100	3.4558	.2880	138.90	173.62	208.35	243.07	277.80	312.52	347.25	434.06	520.87	
1.110	3.4872	.2906	137.65	172.06	206.47	240.88	275.30	309.71	344.12	430.15	516.18	
1.120	3.5186	.2932	136.42	170.52	204.63	238.73	272.84	306.94	341.05	426.31	511.57	
1.130	3.5500	.2958	135.21	169.01	202.82	236.62	270.42	304.23	338.03	422.54	507.04	
1.140	3.5814	.2985	134.03	167.53	201.04	234.54	268.05	301.56	335.06	418.83	502.59	
1.150	3.6128	.3011	132.86	166.07	199.29	232.50	265.72	298.93	332.15	415.19	498.22	
1.160	3.6442	.3037	131.71	164.64	197.57	230.50	263.43	296.36	329.29	411.61	493.93	
1.170	3.6757	.3063	130.59	163.24	195.88	228.53	261.18	293.82	326.47	408.09	489.71	
1.180	3.7071	.3089	129.48	161.85	194.22	226.59	258.96	291.33	323.70	404.63	485.56	
1.190	3.7385	.3115	128.39	160.49	192.59	224.69	256.79	288.89	320.98	401.23	481.48	
1.200	3.7699	.3142	127.32	159.16	190.99	222.82	254.65	286.48	318.31	397.89	477.46	
1.210	3.8013	.3168	126.27	157.84	189.41	220.98	252.54	284.11	315.68	394.60	473.52	
1.220	3.8327	.3194	125.24	156.55	187.86	219.16	250.47	281.78	313.09	391.36	469.64	
1.230	3.8642	.3220	124.22	155.27	186.33	217.38	248.44	279.49	310.55	388.18	465.82	
1.240	3.8956	.3246	123.22	154.02	184.83	215.63	246.43	277.24	308.04	385.05	462.06	
1.250	3.9270	.3272	122.23	152.79	183.35	213.90	244.46	275.02	305.58	381.97	458.37	
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	
1.300	4.0841	.3403	117.53	146.91	176.29	205.68	235.06	264.44	293.82	367.28	440.74	
1.350	4.2412	.3534	113.18	141.47	169.77	198.06	226.35	254.65	282.94	353.68	424.41	
1.400	4.3982	.3665	109.13	136.42	163.70	190.99	218.27	245.55	272.84	341.05	409.26	
1.450	4.5553	.3796	105.37	131.71	158.06	184.40	210.74	237.09	263.43	329.29	395.14	
1.500	4.7124	.3927	101.86	127.32	152.79	178.25	203.72	229.18	254.65	318.31	381.97	
1.550	4.8695	.4058	98.57	123.22	147.86	172.50	197.15	221.79	246.43	308.04	369.65	
1.600	5.0265	.4189	95.49	119.37	143.24	167.11	190.99	214.86	238.73	298.42	358.10	
1.650	5.1836	.4320	92.60	115.75	138.90	162.05	185.20	208.35	231.50	289.37	347.25	
1.700	5.3407	.4451	89.88	112.34	134.81	157.28	179.75	202.22	224.69	280.86	337.03	
1.750	5.4978	.4581	87.31	109.14	130.96	152.79	174.62	196.44	218.27	272.84	327.40	
1.800	5.6549	.4712	84.88	106.10	127.32	148.54	169.77	190.99	212.21	265.26	318.31	
1.850	5.8119	.4843	82.59	103.24	123.88	144.53	165.18	185.82	206.47	258.09	309.71	
1.900	5.9690	.4974	80.42	100.52	120.62	140.73	160.83	180.93	201.04	251.30	301.56	
1.950	6.1261	.5105	78.35	97.94	117.53	137.12	156.71	176.29	195.88	244.85	293.82	
2.000	6.2832	.5236	76.39	95.49	114.59	133.69	152.79	171.89	190.99	238.73	286.48	
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	
2.100	6.5973	.5498	72.76	90.95	109.13	127.32	145.51	163.70	181.89	227.36	272.84	
2.200	6.9115	.5760	69.45	86.81	104.17	121.54	138.90	156.26	173.62	217.03	260.44	
2.300	7.2257	.6021	66.43	83.04	99.64	116.25	132.86	149.47	166.07	207.59	249.11	
2.400	7.5398	.6283	63.66	79.58	95.49	111.41	127.32	143.24	159.15	198.94	238.73	
2.500	7.8540	.6545	61.12	76.39	91.67	106.95	122.23	137.51	152.79	190.99	229.18	

For surface speeds (S) in the middle line (40, etc.) use the tabular values.
For surface speeds in the upper line (20, etc.) use half the tabular values.

For surface speeds in the lower line (120, etc.) use twice the tabular values.
For diameters of 10 D, divide revolutions by 10; for diameters 0.1 D, multiply revolutions by 10.

*****signifies a change in interval in the diameters. Revolutions per minute = $(12 S)/(\pi D)$, where D is the diameter in inches and S is the surface speed in feet per minute.

REVOLUTIONS PER MINUTE FOR ASSIGNED SURFACE SPEEDS

2.50 to 10.00"
(.250 to 1.000")
(25.0 to 100.0")

Diam- eter D	Circumference			S=Surface Speeds, Feet per Minute; Diameters in Inches								
	πD	πD		20	25	30	35		45			
		12		40	50	60	70	80	90	100	125	150
	In.	In.	Ft.									
2.500	7.854	.6545	61.12	76.39	91.67	106.95	122.23	137.51	152.79	190.99	229.18	
2.600	8.168	.6807	58.76	73.46	88.15	102.84	117.53	132.22	146.91	183.64	220.37	
2.700	8.482	.7069	56.59	70.74	84.88	99.03	113.18	127.32	141.47	176.84	212.21	
2.800	8.796	.7330	54.57	68.21	81.85	95.49	109.13	122.78	136.42	170.52	204.63	
2.900	9.111	.7592	52.69	65.86	79.03	92.20	105.37	118.54	131.71	164.64	197.57	
3.000	9.425	.7854	50.93	63.66	76.39	89.13	101.86	114.59	127.32	159.15	190.99	
3.100	9.739	.8116	49.29	61.61	73.93	86.25	98.57	110.90	123.22	154.02	184.83	
3.200	10.053	.8378	47.75	59.68	71.62	83.56	95.49	107.43	119.37	149.21	179.05	
3.300	10.367	.8639	46.30	57.87	69.45	81.02	92.60	104.17	115.75	144.69	173.62	
3.400	10.681	.8901	44.94	56.17	67.41	78.64	89.88	101.11	112.34	140.43	168.52	
3.500	10.996	.9163	43.65	54.57	65.48	76.39	87.31	98.22	109.13	136.42	163.70	
3.600	11.310	.9425	42.44	53.05	63.66	74.27	84.88	95.49	106.10	132.63	159.15	
3.700	11.624	.9687	41.29	51.62	61.94	72.26	82.59	92.91	103.24	129.04	154.85	
3.800	11.938	.9948	40.21	50.26	60.31	70.36	80.42	90.47	100.52	125.65	150.78	
3.900	12.252	1.0210	39.18	48.97	58.76	68.56	78.35	88.15	97.94	122.43	146.91	
4.000	12.566	1.0472	38.20	47.75	57.30	66.84	76.39	85.94	95.49	119.37	143.24	

4.200	13.195	1.0996	36.378	45.473	54.567	63.662	72.757	81.851	90.946	113.68	136.42	
4.400	13.823	1.1519	34.725	43.406	52.087	60.768	69.449	78.131	86.812	108.51	130.22	
4.600	14.451	1.2043	33.215	41.519	49.822	58.126	66.430	74.734	83.037	103.80	124.56	
4.800	15.080	1.2566	31.831	39.789	47.746	55.704	63.662	71.620	79.577	99.47	119.37	
5.000	15.708	1.3090	30.558	38.197	45.837	53.476	61.115	68.755	76.394	95.49	114.59	
5.200	16.336	1.3614	29.382	36.728	44.074	51.419	58.765	66.111	73.456	91.82	110.18	
5.400	16.965	1.4137	28.294	35.368	42.441	49.515	56.588	63.662	70.736	88.41	106.10	
5.600	17.593	1.4661	27.284	34.105	40.926	47.746	54.567	61.388	68.209	85.26	102.31	
5.800	18.221	1.5184	26.343	32.929	39.514	46.100	52.686	59.271	65.857	82.32	98.79	
6.000	18.850	1.5708	25.465	31.831	38.197	44.563	50.930	57.296	63.662	79.58	95.49	
6.200	19.478	1.6232	24.643	30.804	36.965	43.126	49.287	55.448	61.608	77.01	92.41	
6.400	20.106	1.6755	23.873	29.842	35.810	41.778	47.746	53.715	59.683	74.60	89.52	
6.600	20.735	1.7279	23.150	28.937	34.725	40.512	46.300	52.087	57.875	72.34	86.81	
6.800	21.363	1.7802	22.469	28.086	33.703	39.321	44.938	50.555	56.172	70.22	84.26	
7.000	21.991	1.8326	21.827	27.284	32.740	38.197	43.654	49.111	54.567	68.21	81.85	
7.200	22.619	1.8850	21.221	26.526	31.831	37.136	42.441	47.746	53.052	66.31	79.58	
7.400	23.248	1.9373	20.647	25.809	30.971	36.132	41.294	46.456	51.618	64.52	77.43	
7.600	23.876	1.9897	20.104	25.130	30.156	35.182	40.208	45.234	50.259	62.82	75.39	
7.800	24.504	2.0420	19.588	24.485	29.382	34.280	39.177	44.074	48.971	61.21	73.46	
8.000	25.132	2.0944	19.099	23.873	28.648	33.423	38.197	42.972	47.746	59.68	71.62	
8.200	25.761	2.1468	18.633	23.291	27.950	32.608	37.266	41.924	46.583	58.23	69.87	
8.400	26.389	2.1991	18.189	22.736	27.284	31.831	36.378	40.926	45.473	56.84	68.21	
8.600	27.018	2.2515	17.766	22.208	26.649	31.091	35.532	39.974	44.415	55.52	66.62	
8.800	27.646	2.3038	17.362	21.703	26.043	30.384	34.725	39.065	43.406	54.26	65.11	
9.000	28.274	2.3562	16.977	21.221	25.465	29.709	33.953	38.197	42.441	53.05	63.66	
9.200	28.903	2.4086	16.607	20.759	24.911	29.063	33.215	37.367	41.519	51.90	62.28	
9.400	29.531	2.4609	16.254	20.318	24.381	28.445	32.508	36.572	40.635	50.79	60.95	
9.600	30.159	2.5133	15.915	19.894	23.873	27.852	31.831	35.810	39.789	49.74	59.68	
9.800	30.788	2.5656	15.591	19.488	23.386	27.284	31.181	35.079	38.977	48.72	58.47	
10.000	31.416	2.6180	15.279	19.099	22.918	26.738	30.558	34.377	38.197	47.75	57.30	

For surface speeds (S) in the middle line (40, etc.) use the tabular values.

For surface speeds in the upper line (20, etc.) use half the tabular values.

For surface speeds in the lower line (120, etc.) use twice the tabular values.

For diameters of 10 D, divide revolutions by 10; for diameters 0.1 D, multiply revolutions by 10

*****signifies a change in interval in the diameters. Revolutions per minute = (12 S)/(πD) where D is the diameter in inches, and S is the surface speed in feet per minute.

WEIGHTS AND SPECIFIC GRAVITIES

Substance	Average Weight Lb. per Cu. Ft.	Average Specific Gravity	Substance	Average Weight Lb. per Cu. Ft.	Average Specific Gravity
Acid, acetic 90%.....	66.3	1.061	Bluestone.....	130	2.0-2.2
“ fluoric 58%.....	75	1.20	Borax.....	110	1.7-1.8
“ muriatic (hydro- chloric) 40%.....	75	1.20	Boron.....	153	2.45
“ nitric 35%.....	76	1.216	Brass 67% Cu. 33% Zn. cast	519	8.31
“ “ 91%.....	94	1.50	“ high yellow plates.....	535	8.57
“ phosphoric 72%.....	97.2	1.557	“ Muntz metal.....	512	8.20
“ sulphuric 87%.....	112	1.80	“ Naval, rolled.....	530	8.49
“ “ 97%.....	115	1.839	“ Sheet.....	527	8.44
Air, 0° C and 760 mm.....	.08071	(1) .0012929	“ Wire.....	533	8.54
Alcohol, 100%.....	49	.79	Brick, best pressed.....	150	
“ Commercial.....	52	.832	“ common and hard.....	125	
Alum.....	33	.53	“ soft inferior.....	100	
Aluminum, pure, rolled.....	167.1	2.68	Brickwork @ 125 lb./ft. ³ ; 1 cube yard = 1.688 (2000) tons; 1 (2000) ton = 16.0 ft. ³		
“ wire.....	168	2.70	“ coarse, inferior, soft	100	1.5-1.7
“ wrought.....	167	2.67	“ medium quality	120	1.8-2.0
“ bronze 10%.....	480	7.69	“ pressed brick, fine		
“ “ 5%.....	516	8.27	“ joints.....	140	2.2-2.3
“ nickel alloy, annealed.....	170.9	2.74	Bromine.....	199	3.19
“ nickel alloy, cast.....	178.1	2.85	Bronze 90% Cu. 10% Sn.....	541	8.67
“ nickel alloy, rolled.....	172.1	2.76	“ gun.....	546	8.75
“ pure, annealed.....	165.9	2.66	“ Tobin.....	523	8.38
“ cast.....	159.6	2.56	“ 7.9 to 14% Sn.....	509	7.4-8.9
“ molten.....	136.6	2.19			
Ammonia, liquid 29%.....	56	.897	Cadmium.....	540	8.65
“ gas.....	.0478	(.5920)	“ molten.....	499	7.99
Anthracite 1.3 to 1.84; Pa. 1.3 to 1.7.....	93.5	1.5 Av.	Calcite.....	170	2.72
Anthracite broken, loose.....	52-57		Calcium.....	98	1.57
“ mod. shaken.....	56-60		Carbon.....	134	2.15
“ “heaped bushel (77-83).....			Carbon dioxide.....	.1234	(1.5291)
“ “ 40 to 43 ft. ³ per ton.....			“ monoxide.....	.0781	(.9673)
Antimony, cast.....	418	6.70	Caustic soda.....	88	1.41
“ native.....	416	6.66	“ “ lye 66%.....	106	1.70
Arsenic.....	354	5.67	Cedar, white, red, seasoned	22	.32-.38
Asbestos (rock).....	200	3.20	“ American.....	35	.56
Ash, American White, dry.....	38	.61	Cement barrel, 15-30 lb. 20 lbs. Av.....		
“ Seasoned Timber.....	40	.62-.65	“ mortar, Portland, 1 : 2½.....	135	2.16
Ashes, cinders.....	40-45		“ natural, per bbl. net 282 lb.....		
Asphaltum.....	81	1.1-1.5	“ natural, per bag, net, 94 lb.....		
Babbitt.....	454	7.27	“ Portland, loose.....	88-92	
Barium.....	236	3.78	“ “ packed.....	108-115	
Basalt.....	184	2.7-3.2	“ “ per bag net 94 lbs.....		
“ Quarried, piled.....	96		“ “ bbl. net 376 lb.....		
Bauxite.....	159	2.55	“ “ standard propor.....	100	
Beryllium.....	120	1.92	“ “ set.....	183	2.7-3.2
Birchwood.....	41	.65	Cerium.....	417	6.68
Bismuth.....	611	9.79	Chalk.....	156	2.50
“ molten.....	627	10.04	Charcoal, pine.....	23	.28-.44
Bituminous coal, loose heaped bushel (70-78).....			“ oak.....	33	.47-.57
Bituminous coal, broken, loose.....	47-52		“ piled.....	10-14	
“ “ broken, mod. shaken.....	51-56		Chestnut, seasoned.....	41	.66
Bituminous coal, solid 1.2 to 1.5.....	84 Av.	1.35	Chromium.....	428	6.86
Bituminous coal, 43-48 ft. ³ per ton.....			Cinders (coal ashes and clinkers).....	40	
			Cinnabar.....	550	8.81

The specific gravities of solids and liquids refer to water at 4 degrees Centigrade, those of gases, when in (), to air at 0° C. and 760 mm. pressure. Weight of water at 4° C = 62.4283 lb. per cu. ft.

WEIGHTS AND SPECIFIC GRAVITIES

Substance	Average Weight Lb. per Cu. Ft.	Average Specific Gravity	Substance	Average Weight Lb. per Cu. Ft.	Average Specific Gravity
Clay, marl.....	137	2.19	Earth, common loam,		
“ dry in lump, loose.....	63		“ more so, shaken.....	75-90	
“ hard, ordinary.....	150	2.40	“ common loam,		
“ potters, dry, 1.8 to 2.1	119	1.9	“ more so, packed.....	90-100	
“ excavated, damp and			“ soft flowing mud.....	104-112	
“ plastic.....	110		“ common loam,		
“ excavated and gravel,			ditto pressed.....	110-120	
“ dry.....	100		Ebonite.....	72	1.15
“ “ in water.....	80		Elm wood, dry.....	35	.56
Coal, see anthracite;			“ seasoned, white.....	45	.72
bituminous.....			Emery.....	250	4.00
Cobalt.....	546	8.75	Erbium.....	310	4.97
Coke.....	75	1.0-1.4			
“ loose, heaped bushel			Feldspar, orthoclase.....	159	2.5-2.6
“ 35-42 lb.....			Fir, Douglas spruce,		
“ “ good quality.....	23-32		“ seasoned.....	32	.51
“ 1 ton (2000) requires			“ eastern.....	25	.40
63 to 87 ft. ³			Flint.....	162	2.59
Columbium.....	517	8.28			
Concrete, cinder, with			Gallium.....	370	5.93
“ Portland Cem.....	112		Gas, illuminating.....	.028-.036	(.35-.45)
“ conglomerate,			“ natural.....	.038-.039	(.47-.48)
with Portland			Gasoline motor.....	44-47	.71-.75
Cement.....	150		Germanium, molten.....	335	5.36
“ gravel, with			German silver.....	527	8.44
Portland Cem.....	150		Glass, common window.....	156	2.40-2.60
“ limestone, with			“ crown or plate.....	160	2.45-2.72
Portland Cem.....	148		“ crystal.....	184	2.90-3.00
“ sandstone, with			“ flint.....	230	3.68
Portland Cem.....	143		Gneiss, serpentine.....	159	2.4-2.7
“ trap, with Port-			“ loose, in piles.....	96	
land Cement.....	155		Gold, cast, pure or 24-karat.....	1204	19.29
“ loose, unram-			“ pure, hammered.....	1217	19.49
med, 5 to 25%.....			“ std. 22-karat, Au 11,		
lighter, varying			Cu 1.....	1090	17.46
with consistency.....			Granite, syenite.....	175	2.5-3.1
“ masonry, stone,			“ broken.....	96	
sand, cement.....	144	2.2-2.4	“ dressed.....	165	
“ masonry, cem-			“ rubble.....	154	
ent, slag, etc.....	130	1.9-2.3	“ dry.....	138	
“ masonry, cem-			Graphite.....	131	1.9-2.3
ent, cinder, etc.....	100	1.5-1.7	Gravel, sand, dry, loose.....	90-105	
Copper, cast, 8.6 to 8.8.....	542	8.68	“ “ packed.....	100-120	
“ hammered.....	557	8.92	“ “ wet.....	118-120	
“ plates and sheets.....	557	8.92	Greenstone, trap 2.8-3.2.....	187	3.00
“ pure.....	549	8.79	“ quarried, piled.....	107	
“ rolled, 8.8 to 9.0.....	555	8.89	Gunmetal.....	544	8.71
“ wire.....	554	8.87	Gutta-percha.....	61	.98
“ wrought.....	555	8.89	Gypsum, plaster of paris.....	77	
“ ore, pyrites.....	262	4.1-4.3	“ rock, no surface.....		
Cork, dry.....	15	.24	“ water.....	140-145	
Corundum, pure, 3.8 to 4.....		3.9	“ crushed rock.....	90-100	
Cypress wood.....	29	.46	“ ground rock.....	75-80	
			“ ditto, calcined,		
			loose.....	55-65	
Dolomite.....	181	2.90	“ ditto, calcined,		
Duralumin.....	180	2.88	well shaken.....	65-75	
			“ alabaster.....	159	2.3-2.8
Earth, common loam,					
dry, loose.....	72-80		Hemlock wood.....	25	.40
“ common loam,			“ “ seasoned.....	29	.42-.52
dry, shaken.....	82-92		Hickory wood, dry.....	53	.85
“ common loam,			“ “ seasoned.....	49	.74-.84
dry, rammed.....	90-100		Hornblende.....	187	3.0
“ common loam,			Hydrogen.....	.00559	(0.0693)
slightly moist.....	70-76				
“ common loam,			Ice .917 to .922.....	57.4	.92
more so, loose.....	66-68		India Rubber.....	58	.93

The specific gravities of solids and liquids refer to water at 4° C., those of gases, when in (), to air at 0° C. and 760 mm. pressure. Weight of water at 4° C = 62.4283 lb. per cu. ft.

WEIGHTS AND SPECIFIC GRAVITIES

Substance	Average Weight Lb. per Cu. Ft.	Average Specific Gravity	Substance	Average Weight Lb. per Cu. Ft.	Average Specific Gravity
Indium.....	444	7.12	Masonry ashlar, sandstone,		
Iodine.....	309	4.95	bluestone.....	140	2.1-2.4
Iridium.....	1400	22.43	" rubble, granite,		
Iron, cast 6.9 to 7.4	446	7.15 Av.	" syenite, gneiss.....	155	2.2-2.8
" " grey.....	442	7.08	" rubble, lime-		
" foundry,			stone, marble.....	150	2.2-2.6
" cold.....	450	7.21	" rubble, sand-		
" cast grey foundry,			stone, bluestone	130	2.0-2.2
" molten.....	433	6.94	" dry rubble, gran.		
" pure.....	491	7.87	" syen., gneiss.....	130	1.9-2.3
" white cast.....	477	7.64	" dry rubble, lime-		
" wire.....	485	7.77	stone, marble.....	125	1.9-2.1
" wrought.....	480	7.69	" dry rubble, sand-		
" cast, pig.....	450	7.2	stone, bluestone	110	1.8-1.9
" steel.....	489.6	7.843	concrete; see		
" spiegeleisen.....	468	7.50	Concrete.		
" ferro-silicon.....	437	7.00	Mercury at 32° F.....	849	13.60
" ore, hematite.....	325	5.21	" at 68° F.....	846	13.55
" " " in bank	160-180		Mica, 2.75 to 3.1.....	183	2.93
" " " loose.....	130-160		Molybdenum.....	636	10.19
" " limonite.....	237	3.80	Monel metal.....	554	8.87
" " magnetite.....	315	5.05	Mortar, hardened 1.4 to 1.9	103	1.65
" slag.....	172	2.5-3.0	Mud, dry, close.....	80-110	
Lanthanum.....	384	6.15	" river.....	90	
Lead, cast.....	708	11.34	" wet, moderately		
" commercial.....	709.6	11.37	pressed.....	110-130	
" sheet.....	712	11.41	" wet, fluid.....	104-120	
" ore, galena.....	465	7.45	Neodymium.....	434	6.95
" molten.....	664	10.64	Nickel, cast.....	516	8.27
Lignite.....	78	1.1-1.4	" rolled.....	541	8.67
" in piles.....	40-54		" silver (52Cu-26Zn		
Lignum-vitae wood, dry.....	41-83	.66-1.33	22 Ni).....	527	8.44
Lime.....	53-64		Niobium.....	793	12.7
" quick.....	95	1.52	Nitrogen.....	.0784	(0.9714)
" " ground, shaken			Oakwood, heart of old.....	73	1.17
thoroughly			" live, dry .88 to		
93¾ lb. struck			1.02.....	59	.95
bushel.....	75		" red, black, dry.....	32-45	
" " ground, shaken,			" white.....	52	.83
80 lb.....	64		" seasoned,		
Limestone and marble.....	165	2.64	chestnut.....	54	.86
" " " piled.....	95		" seasoned, live.....	59	.95
solid.....	168	2.69	" " red, black	41	.65
Lithium.....	36.8	.59	" " white.....	46	.74
Loam, see earth.....			Oil, animal and vegetable.....	58	.91-.94
Locust wood, dry.....	44	.70	" kerosene 150° to 300° F.	51.7	.83
" seasoned.....	46	.74	" cotton seed.....	60.2	.96
Lye.....	110		" lard.....	57.4	.92
" soda, 66%.....	106	1.70	" linseed.....	58.8	.94
Magnesite.....	187	3.0	" mineral lubricating	57	.91
Magnesium.....	109	1.75	" Navy sperm.....	54	.86
Manganese.....	461	7.38	" olive.....	57	.85
" ore, pyrolusite.....	259	3.7-4.6	" petroleum.....	55	.88
Manganin.....	525	8.41	" signal.....	53	.85
Maple, hard seasoned.....	43	.69	" turpentine.....	54	.86
" white.....	33	.53	" whale.....	58	.93
" dry.....	49	.78	Osmium.....	1403	22.47
Marble (see Limestone).			Oxygen.....	.0892	(1.1056)
Marl.....	140		Palladium.....	749	12.0
Masonry debris.....	90		Paper, calendered.....	50-70	
" of brick; see brick			" strawboard,		
" ashlar, granite,			newspaper.....	33-44	
" syenite, gneiss.....	165	2.3-3.0			
" ashlar, limestone,					
marble.....	160	2.3-2.8			

The specific gravities of solids and liquids refer to water at 4° C., those of gases, when in (), to air at 0° C. and 760 mm. pressure. Weight of water at 4° C = 62.4283 lb. per cu. ft.

WEIGHTS AND SPECIFIC GRAVITIES

Substance	Average Weight Lb. per Cu. Ft.	Average Specific Gravity	Substance	Average Weight Lb. per Cu. Ft.	Average Specific Gravity
Paraffine.....	56	.87-.91	Slags, bank slag.....	67-72	
Peat, piled.....	20-26		" bank screenings.....	98-117	
" dry.....	47	.65-.85	" machine slag.....	96	
Petroleum.....	54	.87	" slag sand.....	49-55	
" refined.....	50	.79-.82	Slate 2.7 to 2.9, see Shale.		
" benzine.....	46	.73-.75	Soapstone, talc, 2.65 to 2.8.	169	2.6-2.8
" gasoline.....	42	.66-.69	Soda ash.....	74	1.19
Phosphate rock, apatite.....	200	3.20	Sodium.....	61	.98
Phosphorus, red.....	146	2.34	Soil.....	70	
" white.....	115	1.84	Spelter 6.8 to 7.2.....	437.5	7.00
Pine wood, white.....	25	.40	Spruce wood.....	31	.50
" " yellow, North'n.....	34	.54	" " old.....	29	.46
" " " South'n.....	45	.72	Spruce, white, black,		
" Oregon, seasoned.....	32	.51	seasoned.....	27	.40-.46
" Red ".....	30	.48	Steam at 212° F.....	.03729	(.4620)
" White ".....	26	.41	Steel.....	489.6	7.84
" Yellow, long-leaf,			Strontium.....	159	2.55
seasoned.....	44	.70	Sulphur.....	125	2.00
" Yellow, short-leaf,			Sycamore wood, dry.....	37	.59
seasoned.....	38	.61			
Pitch.....	69	1.07-1.15	Talc, see soapstone.		
Plaster.....	53		Tar, bituminous.....	75	1.20
" of paris, see			Tellurium.....	390	6.25
gypsum.....			Thallium.....	740	11.85
Platinum.....	1342	21.50	Thorium.....	759	12.16
Poplar wood, dry.....	29	.46	Tin, cast, 7.2 to 7.5.....	459	7.35
" " white Spanish.....	33	.53	" pure.....	455	7.29
" " seasoned.....	30	.48	" ore cassiterite.....	418	6.4-7.0
Porcelain.....	149	2.39	Titanium.....	281	4.5
Porphyry.....	172	2.76	Trap rock, compact.....	188	3.0
Potassium.....	56	.90	" " in pile.....	109	
Pumice, natural.....	40	.37-.90	Tungsten.....	1224	19.6
Quartz, flint.....	165	2.5-2.8	Uranium.....	1667	26.70
Redwood, dry.....	30	.48	Vanadium.....	343	5.49
" seasoned, Calif.....	26	.42	Vapor, alcohol.....	.122	(1.512)
Rhodium.....	787	12.61	" spirits of turpentine.....	.378	(4.68)
Rope.....	42		" water.....	.047	(0.58)
Rosin.....	68.6	1.10			
Rubber, caoutchouc.....	59	.92-.96	Walnut wood, black, dry,		
" goods.....	94	1.0-2.0	seasoned.....	33	.61
			Walnut wood, white,		
Salt, per struck bushel			seasoned.....	26	.42
56 lb.....	45		Water, pure, 32° F. and		
" granulated, piled.....	48		" " 30 in.....	62.417	
Saltpeter, loose.....	68		" " 62° F. and		
Samarium.....	484	7.75	" " 30 in.....	62.355	
Sand, of pure quartz, dry ..	90-106		" " 212° F. and		
" " water			" " 30 in.....	59.830	.9584
filled.....	118-129		" sea.....	64	1.026-
" pure quartz, dry,			" ice.....	56	to 1.030
" mixed grains.....	117				.88-.92
" excavations in water.....	60		White metal (Babbitts).....	456	7.30
" with clay, excava-			Woods metal.....	605	9.69
tions in water.....	65				
Sandstone, bluestone.....	147	2.2-2.5	Zinc, cast.....	428	6.86
" quarried and			" pure.....	446	7.14
" piled.....	82		" rolled.....	449	7.19
" see masonry.....			Zirconium.....	390	6.25
Selenium.....		4.3-4.8			
Shale, slate.....	175	2.7-2.9			
" " quarried, piled.....	92				
Silicon, crystalline.....	151	2.42			
Silver.....	653	10.46			

The specific gravities of solids and liquids refer to water at 4° C., those of gases, when in (), to air at 0° C. and 760 mm. pressure. Weight of water at 4° C. = 62.4283 lb. per cu. ft.

COEFFICIENTS OF LINEAR EXPANSION

For 1 degree Centigrade.

For 1 degree Fahrenheit, multiply by 5/9.

Material	Centigrade	20	20	20	20	20	20	100	200	300	400	500
		to	to	to	to	to	to	to	to	to	to	to
	Fahrenheit	70	70	70	70	70	70	210	390	570	750	930
		to	to	to	to	to	to	to	to	to	to	to
		210	390	570	750	930	1110	390	570	750	930	1110
Aluminum.....	Cast	23.8	24.7	25.7	26.7	27.7	28.7	25.5	27.5	29.5	31.5	33.5
Antimony.....		10.5*										
Arsenic.....		5.0*										
Bismuth.....		13.2*										
Brass, Soft (72 Cu, 28 Zn)												
Rolled & Ann.		17.8	18.5	19.1	19.8	20.5						
Brass, Soft (66 Cu, 34 Zn)												
Rolled & Ann.		19.5	20.0	20.5	21.1	21.6						
Brass, Naval (60 Cu, 1 Sn, 39 Zn)												
Rolled		19.8	20.5	21.2	21.8	22.5						
Bronze, Aluminum.....	Cast	17.6	17.9	19.2								
Bronze, Lead.....	Cast	19.1	19.2	19.4	19.5	19.6						
Bronze, Manganese.....	Cast	20.0	20.4	20.8	21.6	22.7						
Bronze, Nickel.....	Cast	17.3	17.7	18.1	18.4	18.8						
Bronze, Phosphor.....	Cast	18.1	18.4	18.8	19.1	19.4						
Cadmium.....		31.6*										
Carbon (Graphite).....		7.86*										
Cobalt.....		12.36*										
Copper.....	Rolled	16.6	17.1	17.6	18.1	18.6						
Duralumin.....		23.8	24.7	25.7	26.3	27.2						
Gold.....		13.8**										
Gun Metal.....	Cast	18.7	19.1	19.6	20.0	20.4						
Lead.....		27.09*										
Magnesium.....		25.8*										
Monel Metal.....	Rolled	13.9*	14.4*	14.9*	15.5*	16.0*						
".....		13.5*	14.1*	14.7*	15.3*	15.9*						
".....	Cast	16.5*	16.6*	16.8*	17.0*	17.2*						
Muntz Metal (60 Cu, 40 Zn)												
Rolled		19.5	20.3	21.0	28.0		15.5	13.5	14.8	17.2	16.6	17.1
Nickel.....	Rolled	13.1*	13.8*									
Nichrome.....	Rolled	12.4*	13.0*	13.6*	14.1*	14.7*						
Palladium.....		11.76*										
Platinum.....		8.99*										
Silicon.....		7.63*										
Silver.....		19.21*										
Silver Solders.....		19.0*	19.2*	19.6*	20.4*	21.3*						
Tantalum.....		6.5*										
Tin.....		22.95*										
Tungsten.....		4.3*	4.4*	4.5*	4.5*	4.6*		4.5	4.6	4.7	4.8	
Zinc.....		29.76*										

EXPANSION OF WATER

MAXIMUM DENSITY = 1

C°	Volume	C°	Volume	C°	Volume	C°	Volume	C°	Volume	C°	Volume
0	1.000126	10	1.000257	30	1.004234	50	1.011877	70	1.022384	90	1.035829
4	1.000000	20	1.001732	40	1.007627	60	1.016954	80	1.029003	100	1.043116

*Starting at 0°C or 32° F.

**25—100° C or 75—210° F.

Data on coefficient of expansion abstracted from "Symposium on Effects of Temperature on the Properties of Metals," American Society for Testing Materials and American Society of Mechanical Engineers, June 1931—See Mochel, p. 509 on "Thermal Expansion of Metals."

All coefficients of expansion in table have been multiplied by 10⁶. For example, the table gives 12.4, but the actual coefficient is 12.4 x 10⁻⁶ = .0000124.

COEFFICIENTS OF LINEAR EXPANSION

For 1 degree Centigrade.

For 1 degree Fahrenheit, multiply by 5/9.

Material	Centigrade	0 to 100	0 to 200	0 to 300	0 to 400	0 to 500	0 to 600	100 to 200	200 to 300	300 to 400	400 to 500	500 to 600	600 to 700
	Fahrenheit	32 to 212	32 to 390	32 to 570	32 to 750	32 to 930	32 to 1110	212 to 390	390 to 570	570 to 750	750 to 930	930 to 1110	1110 to 1290
Electrolytic Iron.....		12.0		13.3			14.7	13.0	14.5	15.3	15.9	16.8	17.4
Armco Iron.....		12.2	12.8	13.4	13.9	14.5							
Cast Iron:													
1.10 Si, .300 P, 0.70 Mn, 2.75 GC, 3.06 TC.....		11.1	11.6	12.2	12.7	13.2							
2.00 Si, .255 P, 0.93 Mn, 2.48 GC, 3.12 TC.....		10.6	11.3	11.9	12.5	13.2							
1.44 Si, .291 P, 0.85 Mn, 2.88 GC, 3.66 TC.....		10.4	11.1	11.7	12.3	12.9							
Rolled Carbon Steels:													
0.17 C, 0.42 Mn..... Rolled		11.8	12.4	13.0	13.6	14.2							
.08-.18 C, under .55 Mn..... Rolled		12.8	13.3	13.9	14.4	14.9							
S.A.E. 1025..... Rolled		12.0	12.6	13.2	13.7	14.3							
S.A.E. 1035..... Rolled		12.6	13.1	13.6	14.0	14.5							
O. H. Screw Stock													
Gold—Drawn		12.2	12.8	13.5	14.2	14.8							
0.41 C, 0.64 Mn..... Annealed		11.1		12.7			14.3	12.2	14.3	15.8	15.7	16.0	16.6
0.59 C, 0.92 Mn..... Annealed		11.1		12.9			14.6	12.5	14.6	15.4	16.1	16.8	16.6
0.49 C, 1.21 Mn..... Annealed		11.3		12.7			14.5	12.2	14.2	16.3	17.7	15.4	16.7
Forged Carbon Steels:													
0.40-0.45 C, 0.40-0.80 Mn, Nor. and Ann.....		11.3	12.1	12.9	13.6	14.4							
S.A.E. 1025..... Q. & D.		12.2	12.8	13.4	14.0	14.7							
S.A.E. 1055..... do.		11.1	11.8	12.5	13.2	13.9							
Cast Carbon Steels:													
0.25-0.35 C, 0.40-1.00 Mn, Annealed		11.9	12.6	13.3	14.0	14.7							
Nickel Steels:													
0.33 C, 0.78 Mn, 3.59 Ni, Annealed		10.9		12.1			13.8	11.5	13.6	15.2	15.1	15.7	
0.33 C, 0.78 Mn, 3.59 Ni, Q. & D.		10.9	11.6	12.3	12.9	13.6							
5% Ni..... Rolled		11.5	12.0	12.4	12.9	13.4							
35% Ni..... Rolled		3.7		9.2			13.6	8.4	14.1	16.6	18.4	18.8	19.1
36½% Ni. (Invar)†		2.9‡				10.9‡							14.6‡
Nickel-Chromium Steels:													
S.A.E. 3145..... Q. & D.		11.8	12.3	12.9	13.4	14.0							
S.A.E. 3440..... Q. & D.		11.5	12.1	12.7	13.3	13.9							
Chromium-Vanadium Steels:													
S.A.E. 6115..... Annealed		11.6		12.7			14.0	12.5	13.7	14.6	15.2	16.0	15.8
S.A.E. 6135..... Annealed		11.6		12.9			14.6	12.6	14.2	16.0	15.9	16.4	16.9
Chromium-Molybdenum Steels:													
S.A.E. 4140..... Annealed		11.1	11.7	12.3	13.0	13.6							
Stainless Steels:													
0.30 C, 13.00 Cr..... Annealed		10.0		11.0			12.0	10.6	12.0	12.6	13.5	13.9	13.7
0.13 C, 13.50 Cr..... Annealed		10.2	10.5	10.9	11.3	11.7	12.1*						
0.15 C, 18.00 Cr, 8.00 Ni..... Rolled		17.3											20.2@
0.07 C, 18.00 Cr, 8.00 Ni.....		16.0											19.0‡

@ 20—1000° C, or 70—1830° F.

‡ 600—1000° C, or 1110—1830° F.

* 0—800° C, or 32—1470° F.

† Invar 2.9—20° to 126° C; 10.9—20° to 506° C;

14.6—20° to 971° C.

Data on coefficient of expansion abstracted from "Symposium on Effects of Temperature on the Properties of Metals," American Society for Testing Materials and American Society of Mechanical Engineers, June 1931—See Mochel, p. 509 on "Thermal Expansion of Metals."

All coefficients of expansion in table have been multiplied by 10⁶. For example, the table gives 12.4, but the actual coefficient is 12.4 x 10⁻⁶; = .0000124.

PHYSICAL CONSTANTS

OF THE

ALLOY FORMING ELEMENTS

Element	Symbol	Atomic Weight	Melting Point °F	Boiling Point °F	Density Grams per c. c. 20°C.	Atomic Volume c. c. per gram-atom	Mean Linear Coefficient of Thermal Expansion per 1°C x 10 ⁶ (20°C.)	Specific Heat calories (15°) per gram per 1° C. at Room Temp.	Thermal Conductivity at 0° C. calories per c. c. per sec per 1° C.	Electric Resistivity Microhms per c. c. 20° C.	Crystallization Shrinkage Per Cent.	Young's Modulus Lbs. per sq. in. x 10 ⁻⁶
Aluminum	Al	26.96	1220	3272	2.702	9.98	23.03	.214	.485	2.62	6.7	10
Antimony	Sb	121.77	1167	2516	6.684s	18.22	11.4	.049	.044	39.	1.4	11
Arsenic	As	74.96	1497 a	1139	5.7 M.H	13.2	4.7	.0822 e	....	35. f	....	....
					4.7 Blk.	15.9	....	....	....	....	....	....
					2.0 Y.C.	38.0	....	....	....	....	....	....
Beryllium	Be	9.02	2460	2730	1.8	5.0	....	.427 e	(.79)	18.5	....	....
Bismuth	Bi	209.0	519.8	2640	9.80	21.33	13.3	.0293	.020	115.	—3.3	4.6
Cadmium	Cd	112.41	609.6	1413	8.6	13.1	29.8	.060	.223	7.5	4.7	10.0
Calcium	Ca	40.07	1490	2140	1.55	25.9	25. b	.155	(.32)	4.6	....	....
Carbon	C	12.000	....	7600	....	....	....	....	....	....	....	....
Diamond					3.51	3.42	0.9	.121	....	5x10 ²⁰ n	....	....
Graphite			6300	....	2.255	5.32	8.0	.169	.0375	1400	....	....
Cerium	Ce	140.25	1184	2550	6.90	20.33	....	.0423 e	(.019)	78.	....	....
Chromium	Cr	52.01	2939	4000	7.1	7.3	8.2	.106	(.560)	2.6 f	....	....
Cobalt	Co	58.97	2696	5200	8.9	6.6	12.3	.1005	(.150)	9.7	....	....
Copper	Cu	63.57	1981	4170	8.92	7.13	16.6	.0921	.927	1.69	4.1	17.8
Gold	Au	197.2	1945	4700	19.3	10.22	14.2	.0311 k	.707	2.4	5.2	11.1
Indium	In	114.8	311	2640	7.3	15.7	33.	.0568 e	(.162)	9.	....	....
Iridium	Ir	193.1	4262	8670	22.4	8.62	6.5	.0323 e	.141	6.	....	71
Iron	Fe	55.84	2795	5430	7.86	7.10	11.7	.107	.148	10.	....	30
Alpha Gamma												
Lead	Pb	207.20	621.5	2950	11.34	18.27	29.1	.0306	.084	21.9	3.4	1
Lithium	Li	6.939	367	2190	0.53	13.1	55.	.79 f	.167	9.3	1.5	....
Magnesium	Mg	24.32	1204	2030	1.74	14.0	25.6	.25	.370	4.46	4.2	6.25
Manganese	Mn	54.93	2300	3450	7.2	7.6	23.	.107 f	(.291)	5.	....	....
Mercury	Hg	200.61	—37.97	674.4	13.5465	14.810	182.	.0334 g	.020	....	3.75	....
Molybdenum	Mo	96.0	4750	6700	10.2	9.4	....	.065 h	.349	4.77	....	....
Nickel	Ni	58.69	2646	5250	8.90	6.59	12.8	.105	.140	6.9	....	30
Osmium	Os	190.8	4900	9570	22.48	8.488	6.1	.031 h	(.162)	9.	....	....
Palladium	Pd	105.7	2831	3990	12.0	8.9	11.8	.0587 k	.161	10.8	....	14
Phosphorus	P	31.024	111.4 Y.	536	1.82 YH	17.1	125. d	.18 m	....	10 ¹⁷ r	....	....
			....	....	2.20 R C	14.1	....	.19 t	....	....	....	....
Platinum	Pt	195.23	3190	7770	21.45	9.102	8.9	.0324	.166	10.5	....	23.5
Rhodium	Rh	102.91	3550	4500	12.5	8.2	8.4	.058 e	.214	5.1	....	42
Ruthenium	Ru	101.7	4440	4890	12.2	8.3	9.1	.051 e	(.145)	10.	....	....
Silicon	Si	28.06	2590	4710	2.4	11.7	2.8—7.3	.176	....	85 x 10 ³	....	....
Silver	Ag	107.880	1761	3540	10.5	10.3	18.9	.0558	1.00	1.62	5.0	10.3
Sulphur	S	32.065	235.0	....	2.07 R	15.5	64 p	.171	.0005	2 x 10 ²³	....	....
			246.2	832.3	1.96M	16.4	....	.179	....	....	....	....
Tantalum	Ta	181.5	5160	7410	16.6	10.93	7.	.036	.130	15.	....	27
Thorium	Th	232.15	3353	5400	11.2	20.7	....	.0276 e	(.081)	18.	....	....
Tin	Sn	118.70	449.3	4100	7.31WT	16.24	20.	.0542	.157	11.4	2.7	5.9
					5.75GC	20.64	....	....	....	....	....	....
Titanium	Ti	47.9	3270	5400	4.5	10.7	....	.144 e	(.485)	3.	....	....
Tungsten	W	184.0	6100	10650	19.3	9.53	4.	.034 h	.382	5.48	....	60
Uranium	U	238.17	3360	....	18.7	12.7	....	.028 e	(.0243)	60.	....	....
Vanadium	V	50.96	3110	5400	5.96	8.55	....	.115 e	....	....	....	....
Zinc	Zn	65.38	787.0	1665	7.14	9.16	33.	.0925	.270	6.	6.5	12.4
Zirconium	Zr	91.	3090	5250	6.4	14.2	....	.0662 e	(.0086)	170. f	....	....

a, 36 atmospheres pressure. b, 0° to 21° C. c, —163 to —18° C. d, 0° to 40° C. e, 0° to 100° C. f, 0° C. g, —40° C. h, 20 to 100° C. k, 18° C. m, 9° C. n, 15° C. p, 40° C. r, 11° C. s, 25° C. t, —21 to +7° C. () Thermal Conductivity = 1.455 ÷ Electric Resistivity (for Metals only). Results are approximate to 2 or 3%.

See p. 297 for miscellaneous conversion coefficients.

MISCELLANEOUS DATA

SPECIFIC HEATS AND MELTING POINTS						SPECIFIC ELECTRICAL RESISTANCE Ordinary Temperatures		
Substance	Average Specific Heat	Average Watt-Hrs. for 1 Lb. 1° C.	Average Watt-Hrs. for 1 Lb. 1° F.	Heat of Fusion Watt-Hrs. per Lb.	Melting Point Degrees C.	Pounds per Cube Foot	Metal	Specific Resistance
Air (68° F.)	.237	.125	.0695	-----	-----	0.08074	Aluminum	
Aluminum	.22	.116	.065	45.9	660	160.	99.57%	2.828
Brass	.091	.048	.0266	-----	850-1200	511-536	Brass	6-9
Carbon	.204	.107	.0595	-----	-----	-----	Climax	28.7-19.1
Copper	.094	.0495	.0275	22.8	1083	555.	Cobalt	1.98
Graphite	.20	.105	.0583	-----	-----	-----	99.8%	9.7
Iron, Gray	.11	.058	.0322	12.2	1200	450.	Constantan	17.7
cast	.16	.116	.0645	-----	-----	-----	Copper, annealed	3.52
Lead, solid	.031	.0163	.00905	3.1	327.4	710.	Copper, pure	1.7241
Lead, fluid	.0471	.0248	.0138	-----	-----	-----	Ger. Silver (18X)	100.
Nickel	.11	.058	.0322	2.45	1452	517-573	Iron, 99.98%	1.692
Paraffin, solid	.62	.326	.181	-----	38-56	54.25-56.75	(18X)	30-40
Paraffin, fluid	.69	.363	.202	-----	-----	-----	Wrought	10
Pitch	.71	.374	.208	18.5	-----	52.4-57	Iron	5.7-4.3
Rosin, solid	-----	-----	-----	-----	-----	67	Lead	17.24
Solder	-----	-----	-----	-----	-----	67	Manganin	13.9
(1 tin, 1 lead)	-----	-----	-----	5.30	205	555.	Mercury	22
Solder	-----	-----	-----	-----	-----	-----	Molybden.	44
(2 tin, 1 lead)	-----	-----	-----	-----	-----	-----	Nickel	95.8
Tallow	-----	-----	-----	9.0	185	520.	Nichrome	1.8
Tar	-----	-----	-----	-----	33.3	57-60.5	Platinum	30.3
Tin, solid	.056	.0295	.0164	7.4	232	62-63.4	Silver	22.1
Tin, fluid	.064	.0337	.0187	-----	-----	455.	Superior 23	1.724
Type Metal*	.039	.0206	.0114	-----	-----	436.	Tungsten	10
Water (68°)	1.0	.527	.293	42.3	0	660.		1.62
Wax, Bees	-----	-----	-----	22.4	61-68	62.42		86
Zinc, cast	.093	.049	.0272	14.8	419.4	60-61		2
Zinc, fluid	.12	.063	.035	-----	-----	439-446.5		5.4
	-----	-----	-----	-----	-----	404.		31.9

* 80 parts lead, 20 parts antimony.

WORK OR HEAT UNITS

- 1 Kw.-Hr. = 22,761 lb. water heated 62 to 212° F.
 = 3,518 lb. water evaporated from and at 212° F. = .2411 lb. carbon oxidized at 62° F.
- 1 H.p.-Hr. = .17980 lb. carbon oxidized at 62° F. = 2,6233 lb. water evaporated from and at 212° F.
 = 16,973 lb. water heated from 62 to 212° F.
- 1 lb. carbon oxidized at 62° F. } = 14,155 B.t.u. = 1.11 lb. coal oxidized at 62° F. = 2.5 lb. dry wood oxidized.
 = 23.6 cube feet of 600 B.t.u. per ft³ illuminating gas oxidized at 62° F. = 4,1474 Kw.-Hr. = 5,5618 H.p.-Hr.
 = 11,012,000 ft. lb. = 14,590 lb. water evaporated from and at 212° F. = 94,398 lb. water heated from 62 to 212° F.
- 1 lb. water evaporated from and at 212° F. } = .28427 Kw.-Hr. = .38121 H.p.-Hr. = 970.2 B.t.u. = 754,800 ft.-lb. = .068540 lb. carbon oxidized at 62° F. = 104,355 kg.-m. = 1,023,400 joules.
- Calorie (large or kilogram) = 3,968 B.t.u. B.t.u. = .2520 Calories.
 Calories per kilogram = 1.8 B.t.u. per pound. B.t.u. per pound = .5556 Calories per Kilogram.
 Calories per liter = 112.366 B.t.u. per cube foot. B.t.u. per cube foot = .0088995 Calories per liter.
 Calories per cube meter = .11237 B.t.u. per cube foot. B.t.u. per cube foot = 8.8998 Calories per cube meter.

MISCELLANEOUS CONVERSIONS.

- Atomic Volume:—Cube inches per pound atom = 27.680 x c.c. per gram atom.
 Thermal Conductivity:—B.t.u. (mean) per hour per degree F. per square foot per foot = 241.86 x cal is: per sec. per 1° C., per cm² per cm.
 Electrical Resistivity:—Microhms per sq. in. per ft. = 4,7244 x microhms per cm² per cm.
 Ohms per mil foot = 6.0153 x “ per cm² per cm.

WEIGHTS AND MEASURES

WEIGHTS. United States and British. The grain is the unit. 1 grain = 0.0647987 grams.

AVOIRDUPOIS	Grains	Drams	Ounces	Pounds	Hundred-weight 1 cwt.	Gross Tons
Net ton = 2,000 lb. = .892857 gross tons = 1.215278 Troy Lb. 1 stone = .125 cwt.	1. 27.34375 437.5 7000. 784000. 15680000.	.03657 1. 16. 256. 28672. 573440.	.002286 .0625 1. 16. 1792. 35840.	.000143 .003906 .0625 1. 112. 2240.	.00000128 .00003488 .00055804 .0089286 1. 20.	.000000064 .000001744 .00002790 .0004464 .05 1.
TROY	Grains	Pennyweight	Ounces	Pounds	175 Troy Ounces = 192 Avoirdupois Ounces. 1 Pound Troy = .822857 Lb. Avoir.	
	1 24 480 5760	.041667 1. 20. 240.	.0020833 .05 1. 12.	.0001736 .0041667 .0833333 1.		
APOTHECARIES'	Grains	Scruples	Drams	Ounces	Pounds	Carat. About 3.2 grains. Carat, International, 205 milligrams = 3.168 grains. Carat, sometimes 200 milligrams. 1 ounce = 31.1035 grams. Apothecaries' pound and ounce as for Troy.
	1 20 60 480 5760	.05 1. 3. 24. 288.	.016667 .333333 1. 8. 96.	.0020833 .0416667 .125 1. 12.	.000173611 .0034722 .0104167 .0833333 1.	

LINEAR MEASURE. United States and British. But, 1 yard U. S. = 1.0000029 yds., British
1 yard British = 0.9999971 yds., U. S

COMMON MEASURE STATUTE	Inches	Feet	Yards	Rods	Furlongs	Miles
1 U. S. League = 3 statute miles = 24 furlongs	1 12 36 198 7920 63360	.08333 1. 3. 16.5 660. 5280.	.02778 .33333 1. 5.5 220. 1760.	.0050505 .0606061 .1818182 1. 40. 320.	.00012626 .00151515 .00454545 .025 1. 8.	.00001578 .00018939 .00056818 .003125 .125 1.

**ROPE AND CABLE
MEASURE**

1 inch = .111111 span = .013889 fathom = .0001157 cable's length.
1 span = 9 inches = .125 fathom = .00104167 cable's length.
1 fathom = 6 feet = 8 spans = 72 inches = .008333 cable's length.
1 cable's length = 120 fathoms = 720 feet = 960 spans = 8640 inches.

NAUTICAL MEASURE

1 nautical mile, as adopted by the United States Coast and Geodetic Survey, equals
the length of 1 minute of arc of a great circle of a sphere whose surface equals
that of the earth = 6080.20 feet = 1.1516 statute miles.
1 league = 3 nautical miles = 18240.60 feet.

GUNTER'S CHAIN

1 link = 7.92 inches = .01 chain = .000125 miles.
1 chain = 100 links = 66 feet = 4 rods = .0125 miles.
1 mile = 80 chains = 8000 links.

SQUARE OR LAND MEASURE. United States and British.

COMMON MEASURE STATUTE	Square Inches	Square Feet	Square Yards	Square Rods	Acres	Square Miles
	1 144 1296 39204 6272640	.006944 1. 9. 272.25 43560. 27878400.	.0007716 .1111111 1. 30.25 4840. 3097600.	.03306 1. 160. 102400.	.0002066 .00625 1. 640.	.00000977 .0015625 1.

1 rod = 40 square rods. Square of 1 acre = 208.7103 feet square.
1 acre = 4 rods. 1 square chain (Gunter's) = 16 sq. rods = $\frac{1}{160}$ acre.
1 sq. rod, sq. pole, or sq. perch = 625 sq. links = $\frac{1}{160}$ acre

WEIGHTS AND MEASURES

CUBIC OR SOLID MEASURE		1 cubic inch = .0005787 cubic foot = .000021433 cubic yard. 1 cubic foot = 1728 cubic inches = .03703704 cubic yard. 1 cubic yard = 27 cubic feet = 46656 cubic inches. 1 cord of wood = 128 cubic feet = Solid 4 x 4 x 8 feet. 1 perch of masonry = 24.75 cubic feet = Solid 16.5 x 1.5 x 1 foot. It is usually taken as 25 cubic feet. 1 British Imperial Gallon (dry or liquid) = 1.03202 U. S. dry gallon = 1.20091 U. S. liquid gallon.						
DRY MEASURE		Pints	Quarts	Gallons	Pecks	Bushels	Cubic Inches	1 heaped bushel = 1.25 struck bushels, but cone must not be less than 6 inches high.
United States only		2	.50	.125	.0625	.015625	33.6003125	
		1	.250	.25	.125	.03125	67.200625	
		8	4.	1.	.5	.125	268.80025	
		16	8.	2.	1.	.250	537.605	
		64	32	8.	4.	1.	2150.42	
LIQUID MEASURE		Gills	Pints	Quarts	Gallons	Barrels	Cubic Inches	British Imperial Gallon = 277.410 cubic inches = 4545.9631 cm ³ . = 10 pounds avoirdupois of pure water at 62° F. and barometer at 30 inches. 1 fluid dram = 60 minims = .125 fluid ounce = .0078125 pint. 1 fluid ounce 480 minims (m) = 8 fluid drams = .0625 pint = 29.574 cm ³ .
United States only		1	.25	.125	.03125	.000992	7.21875	
		4	1.	.5	.125	.003968	28.875	
		8	2.	1.	.25	.007937	57.75	
		32	8.	4.	1.	.031746	231.	
		1008	252.	126.	31.5	1.	7276.5	

LENGTH, CAPACITY, WEIGHT, MEASURES	LENGTH	Kilometer	Hecto- meter	Decameter	Meter	Decimeter	Centimeter	Millimeter
	CAPACITY	Kiloliter	Hectoliter	Decaliter	Liter	Deciliter	Centiliter	Milliliter
	WEIGHT	Kilogram	Hectogram	Decagram	Gram	Decigram	Centigram	Milligram
		1	10 1	100 10 1	1000 100 10 1 .1 .01 .001	10000 1000 100 10 1 .1 .01	100,000 10000 1000 100 10 1 .1	1000000 100000 10000 1000 100 10 1

1 myriameter = 10 kilometers = 10,000 meters.
 1 tonne = 1000 kilograms = 100 myriagrams = 10 quintals.
 1 liter = 1 cubic decimeter.
 1 gram = Weight of 1 cubic centimeter of distilled water at its maximum density at sea level in the latitude of Paris with the barometer at 760 millimeters of mercury.

	Square Kilometer	Square Hecto-meter, Hectare	Square Decameter, Are	Square Meter, Centiare	Square Decimeter	Square Centimeter	Square Millimeter
SQUARE or SURFACE MEASURE	1	100	10000	1000000	1000000	1000000	1000000
		1	100	10000	10000	10000	10000
		.01	1	1	1	1	1
		.0001	.01	.01	.01	.01	.01
		.000001	.0001	.0001	.0001	.0001	.0001
			.000001	.000001	.0001	.01	1
1 square myriameter = 100 square kilometers = 100,000,000 square meters.							

CUBIC MEASURE	Cubic Decameter	Cubic Meter	Cubic Decimeter	Cubic Centimeter	Cubic Millimeter
	1	1000	1000000	1000000000	1000000000
	.001	1	1000	1000000	1000000
	.000001	.001	1	1000	1000000
	.000000001	.000001	.001	1	1000
	.000000001	.000001	.001	.001	1
1 cubic meter = 1 kiloliter = 1 stere.					

EQUIVALENTS OF MEASURE

LENGTHS

1 meter (m) = 10 decimeters (dm) = 100 centimeters (cm) = 1000 millimeters (mm).
 1 meter (m) = 0.1 decameter (dkm) = 0.01 hectometer (hm) = 0.001 kilometer (km).
 1 meter (m) = 39.37 inches, U. S. Standard = 39.370113 inches, British Standard.
 1 millimeter (mm) = 1000 microns (μ) = 0.03937 inch = 39.37 mils.

Meters, m.	Inches, In.	Feet, ft.	Yard, yd.	Rods, r.	Chains, ch.	Miles, U. S.		Kilometers, km.
						Statute	Nautical	
1	39.37	3.28083	1.09361	0.19884	0.04971	0.(3)6214	0.(3)5396	0.001
0.02540	1	0.08333	0.02778	0.(2)5051	0.(2)1263	0.(4)1578	0.(4)1371	0.(4)2540
0.30480	12	1	0.33333	0.06061	0.01515	0.(3)1894	0.(3)1645	0.(3)3048
0.91440	36	3	1	0.18182	0.04545	0.(3)5682	0.(3)4934	0.(3)9144
5.02921	198	16.5	5.5	1	0.25	0.(2)3125	0.(2)2714	0.(2)5029
20.1168	792	66	22	4	1	0.01250	0.01085	0.02012
1609.35	63360	5280	1760	320	80	1	0.86839	1.60935
1853.25	72962.4	6080.20	2026.73	368.497	92.1242	1.15155	1	1.85325
1000	39370	3280.83	1093.61	198.838	49.7096	0.62137	0.53959	1

1 international geographical mile = $1/15^\circ$ at equator = 7422 m = 4.611808 U. S. statute miles.
 1 international nautical mile = $1/60^\circ$ at meridian = 1852 m = 0.999326 U. S. nautical miles.
 1 U. S. nautical mile = 6080.20 feet = 1.15155 statute miles = 1853.25 meters.
 1 British nautical mile = 6080.00 feet = 1.15152 statute miles = 1853.19 meters.

SURFACES AND AREAS

1 sq. meter (m^2) = 100 sq. decimeters (dm^2) = 10000 sq. centimeters (cm^2)
 1 sq. meter (m^2) = 0.01 are (a) = 0.0001 hectare (ha).
 1 sq. millimeter (mm^2) = 0.01 cm^2 = 0.00155 sq. inch = 1973.5 circular mils.
 1 are (a) = 1 sq. decameter (dkm) = 0.0247105 acre.

Sq. Meters, m^2 .	Sq. Inches, sq. in.	Sq. Feet, sq. ft.	Sq. Yards, sq. yd.	Sq. Rods, sq. r.	Acres, A	Hectares, ha.	Sq. Miles, Statute	Sq. Kilo- meters, km^2 .
1	1550.00	10.7639	1.19599	0.03954	0.(3)2471	0.0001	0.(6)3861	0.(5)1
0.(3)6452	1	0.(2)6944	0.(3)7716	0.(4)2551	0.(6)1594	0.(7)6452	0.(9)2491	0.(9)6452
0.09290	144	1	0.11111	0.(2)3673	0.(4)2296	0.(5)9290	0.(7)3587	0.(7)9290
0.83613	1296	9	1	0.03306	0.(3)2066	0.(4)8361	0.(6)3228	0.(6)8361
25.2930	39204	272.25	30.25	1	0.00625	0.(2)2529	0.(5)9766	0.(4)2529
4046.86	6272640	43560	4840	160	1	0.40469	0.(2)1563	0.(2)4047
10000	15499969	107639	11959.9	395.367	2.47105	1	0.(2)3861	0.01
2589999	-----	27878400	3097600	102400	640	259.000	1	2.59000
1000000	-----	10763867	1195985	39536.7	247.105	100	0.38610	1

Notation .(5) = .00000. For example, .(7)232 = .0000000232.

EQUIVALENTS OF MEASURE

VOLUME AND CAPACITY

1 cu. meter (m³) = 1000 cu. decimeters (dm³) = 1000000 cu. centimeters (cm³).
 1 liter (l) = 10 deciliters (dl) = 100 centiliters (cl) = 1000 milliliters (ml) = 1000 cu. centimeters, (cm³ or c.c.).
 1 liter (l) = 0.1 decaliter (dkl) = 0.01 hectoliter (hl) = 1 cu. decimeter (dm³).

Cubic Decimeters, dm ³ or Liters, l	Cubic Inches, cu. in.	Cubic Feet, cu. ft.	Cubic Yards, cu. yd.	U. S. Quarts		U. S. Gallons		U. S. Bushels, bu.
				Liquid, l. qt.	Dry, d. qt.	Liquid, l. gal.	Dry, d. gal.	
1	61.0234	0.03531	0.(2)1308	1.05668	0.90808	0.26417	0.22702	0.02838
0.01639	1	0.(3)5787	0.(4)2143	0.01732	0.01488	0.(2)4329	0.(2)3720	0.(3)4650
28.3170	1728	1	0.03704	29.9221	25.7140	7.48055	6.42851	0.80356
764.559	46656	27	1	807.896	694.279	201.974	173.570	21.6962
0.94636	57.75	0.03342	0.(2)1238	1	0.85937	0.25	0.21484	0.02686
1.10123	67.2006	0.03889	0.(2)1440	1.16365	1	0.29091	0.25	0.03125
3.78543	231	0.13368	0.(2)4951	4	3.43747	1	0.85937	0.10742
4.40492	268.803	0.15556	0.(2)5761	4.65460	4	1.16365	1	0.125
35.2393	2150.42	1.24446	0.04609	37.2368	32	9.30920	8	1

1 liter per second = 2.11887 cubic feet per minute = 15.8502 U. S. gallons per minute.

1 U. S. gallon = 0.832705 British Imperial gallons.

Weight of water at maximum density, 4°C, 45° Lat., at sea level, 760 mm barometer:

1 cu. ft. = 62.4283 lbs. av. = 28.3170 kg. 1 cu. in. = 0.57804 oz. av. = 16.3872 g.

1 gal., U. S. liquid = 8.34545 lbs. = 3.78543 kg.

1 gal., British Imperial = 10.0221 lbs. = 4.5459631 kg.

MASSES AND WEIGHTS

1 gram (g) = 10 decigrams (dg) = 100 centigrams (cg) = 1000 milligrams (mg).

1 gram (g) = 0.1 decagram (dkg) = 0.01 hectogram (hg) = 0.001 kilogram (kg).

1 kilogram (kg) = 1 liter of water, (4°C, 45° Lat. at sea level) = 15432.35639 grains, U. S. and British Standard.

Kilograms, kg.	Grains, gr.	Ounces		Pounds		Tons		
		Troy, oz. t.	Avoir., oz. av.	Troy, lb. t.	Avoir., lb. av.	Net (Short), 2000 lbs.	Gross, (Long), 2240 lbs.	Metric, 1000 kg.
1	15432.4	32.1507	35.2740	2.67923	2.20462	0.(2)1102	0.(3)9842	0.001
0.(4)6480	1	0.(2)2083	0.(2)2286	0.(3)1736	0.(3)1429	0.(7)7143	0.(7)6378	0.(7)6480
0.03110	480	1	1.09714	0.08333	0.06857	0.(4)3429	0.(4)3061	0.(4)3110
0.02835	437.5	0.91146	1	0.07595	0.06250	0.(4)3125	0.(4)2790	0.(4)2835
0.37324	5760	12	13.1657	1	0.82286	0.(3)4114	0.(3)3674	0.(3)3732
0.45359	7000	14.5833	16	1.21528	1	0.00050	0.(3)4464	0.(3)4536
907.185	14000000	29166.7	32000	2430.56	2000	1	0.89286	0.90719
1016.05	15680000	32666.7	35840	2722.22	2240	1.12	1	1.01605
1000	15432356	32150.7	35274.0	2679.23	2204.62	1.10231	0.98421	1

1 long hundredweight (1cwt.) = 1/20 long ton = 4 quarters = 8 stone = 112 lbs. = 50.8024 kg.

Notation .(5) = .00000. For example, .(7)232 = .0000000232.

EQUIVALENTS OF MEASURE

FORCES OR WEIGHTS PER UNITS OF LENGTH (LINEAR WEIGHTS)

1 dyne per centimeter = 0.00101972 g/cm = .000183719 poundal/in.
 1 gram per centimeter = 980.665 dynes/cm = 0.180166 poundal/in.
 1 poundal per inch = 5443.11 dynes/cm = 5.55043 g/cm = .0310810 pound/in.

Grams per Centimeter, g/cm	Grains per Inch, gr./in.	Pounds per Inch, lb./in.	Pounds per Foot, lb./ft.	Pounds per Yard, lb./yd.	Kilograms per Meter, kg/m	Net Tons, (2000 lbs.), per Mile	Gross Tons, (2240 lbs.), per Mile	Metric Tons, (1000 kg), per Kilometer
1	39.1983	0.(2)5600	0.06720	0.20159	0.10	0.17740	0.15839	0.10
0.02551	1	0.(3)1429	0.(2)1714	0.(2)5143	0.(2)2551	0.(2)4526	0.(2)4041	0.(2)2551
178.579	7000	1	12	36	17.8579	31.6800	28.2857	17.8579
14.8816	583.333	0.08333	1	3	1.48816	2.64000	2.35714	1.48816
4.96054	194.444	0.02778	0.33333	1	0.49605	0.88000	0.78571	0.49605
10	391.983	0.05600	0.67197	2.01591	1	1.77400	1.58393	1
5.63697	220.960	0.03157	0.37879	1.13636	0.56370	1	0.89286	0.56370
6.31341	247.475	0.03535	0.42424	1.27273	0.63134	1.12	1	0.63134

FORCES OR WEIGHTS PER UNITS OF AREA (PRESSURE)

1 dyne per sq. centimeter = 0.00101972 g/cm² = 0.000466646 poundals/in².
 1 gram per sq. centimeter = 980.665 dynes/cm² = 0.457623 poundals/in².
 1 poundal per sq. inch = 2142.95 dynes/cm² = 2.18520 g/cm² = .0310810 pound/in².

Kilograms per Sq. Centimeter, kg/cm ²	Pounds per Sq. Inch, lb./in. ²	Pounds per Sq. Foot, lb./ft. ²	Net Tons, (2000 lbs.), per Sq. Foot	Atmospheres, Standard, 760 mm	Columns of Mercury, (Hg) 13.59593 Sp. G.		Column of Water, Max. Density 4° C	
					Millimeters	Inches	Meters	Feet
1	14.2234	2048.17	1.02408	0.96778	735.514	28.9572	10	32.8083
0.07031	1	144	0.07200	0.06804	51.7116	2.03588	0.70307	2.30665
0.(3)4882	0.(2)6944	1	0.00050	0.(3)4725	0.35911	0.01414	0.(2)4882	0.01602
0.97648	13.8889	2000	1	0.94502	718.216	28.2762	9.76482	32.0367
1.03329	14.6969	2116.35	1.05818	1	760	29.9212	10.3329	33.9005
0.(2)1360	0.01934	2.78468	0.(2)1392	0.(2)1316	1	0.03937	0.01360	0.04461
0.03453	0.49119	70.7310	0.03537	0.03342	25.4001	1	0.34534	1.13299
0.10	1.42234	204.817	0.10241	0.09678	73.5514	2.89572	1	3.28083
0.03048	0.43353	62.4283	0.03121	0.02950	22.4185	0.88262	0.30480	1

FORCES OR WEIGHTS PER UNITS OF VOLUME (DENSITY)

1 dyne per cu. centimeter = 0.00101972 gram/cm³ = 0.00118528 poundals/in³.
 1 gram per cu. centimeter = 980.665 dynes/cm³ = 1.162366 poundals/in³.
 1 poundal per cu. inch = 843.680 dynes/cm³ = 0.860314 g/cm³ = .0310810 pound/in³.

Grams per Cu. Centimeter, g/cm ³	Pounds per Cu. Inch, lb./in. ³	Pounds per Cu. Foot, lb./ft. ³	Pounds per Cu. Yard, lb./yd. ³	Kilograms per Cu. Meter, kg/m ³	Pounds per Bushel, U. S.	Pounds per Gallon, Dry, U. S.	Pounds per Gallon, Liquid, U. S.	Kilograms per Hectoliter, kg/hl
1	0.03613	62.4283	1685.56	1000	77.6893	9.71116	8.34545	100
27.6797	1	1728	46656	27679.7	2150.42	268.803	231	2767.97
0.01602	0.(3)5787	1	27	16.0184	1.24446	0.15556	0.13368	1.60184
0.(3)5933	0.(4)2143	0.03704	1	0.59327	0.04609	0.(2)5761	0.(2)4951	0.05933
0.001	0.(4)3613	0.06243	1.68556	1	0.07769	0.(2)9711	0.(2)8345	0.10
0.01287	0.(3)4650	0.80356	21.6962	12.8718	1	0.125	0.10742	1.28718
0.10297	0.(2)3720	6.42851	173.570	102.974	8	1	0.85937	10.2974
0.11983	0.(2)4329	7.48052	201.974	119.826	9.30918	1.16365	1	11.9826
0.01	0.(3)3613	0.62428	16.8557	10	0.77689	0.09711	0.08345	1

The dyne is not affected by g. It will accelerate a free mass of 1 gram 1 cm. per second per second. A poundal is a similar force unaffected by g which will accelerate a pound mass 1 ft. per second per second. 1 poundal = 13,825.525 dynes.

Masses remain unchanged irrespective of location. The gravitational **force**, however, on a standard mass, varies with location. The standard acceleration of gravity, g, is 980.665 cm/sec² or 32.1740 ft./sec² for which the weight of a pound of mass is a force of 1 pound, and the weight of a mass of 1 kilogram is a force of 1 kilogram, thereby defining the lb. and kg. as units of force.

Notation: .(5) = .00000. For example, .(7)232 = .0000000232

EQUIVALENTS OF MEASURE

ENERGY, WORK, HEAT

1 dyne-centimeter = 1 erg = 0.00101972 gram-centimeter = 0.(7)737561 foot-pound.
 1 gram-centimeter = 980.665 ergs = 0.(4)723301 foot-pound.
 1 foot-pound = 13558208 ergs = 13825.5 gram-centimeters.

Kilogram-meters, kg-m	Foot-Pounds, ft.-lbs.	Horsepower-hour		Poncellet-hours, 100 kg-m-h	Kilowatt-hours, kw-h	Joules, 10 ⁷ ergs, J	Thermal Units	
		U. S., H. P.-h	Metric, 75 kg-m-h				B. T. U.	Calories, kg-cal
1	7.23300	.(5)365303	.(5)370370	.(5)277778	.(5)272406	9.80665	.(2)929717	.(2)234329
.138255	1	.(6)505051	.(6)512056	.(6)384042	.(6)376616	1.355821	.(2)128538	.(3)323972
273,745	1980000	1	1.013872	.760404	.745700	2684525	2545.06	641.464
270,000	1952910	.986318	1	.750000	.735497	2647796	2510.23	632.687
360,000	2603879	1.315091	1.333333	1	.980665	3530394	3346.98	843.583
367,099	2655223	1.341022	1.359624	1.019718	1	3600000	3412.98	860.217
.1019718	.737562	.(6)372506	.(6)377673	.(6)283255	.(6)277778	1	.(3)948049	.(3)238949
107.5599	777.980	.(3)392919	.(3)398370	.(3)298777	.(3)293000	1054.800	1	.252044
426.7521	3086.70	.(2)155894	.(2)158056	.(2)118542	.(2)116250	4185.000	3.96758	1

POWER, RATE OF ENERGY AND HEAT

1 erg per sec. = 1 dyne-cm/sec. = 0.00101972 gram-cm/sec. = 0.(7)737561 foot-pound/sec.
 1 gram-centimeter per second = 980.665 ergs/sec. = 0.(4)723301 foot-pound/sec.
 1 foot-pound per second = 13558208 ergs/sec. = 13825.5 gram-cm/sec.

Kilogram-meters per Second, kg-m/sec.	Foot-pounds per Second, ft.-lbs./sec.	Horsepower		Poncellet 100 kg-m/sec.	Kilowatt, kw.	Watts, 10 ⁷ ergs/sec.	Thermal Units per Sec.	
		U. S., 550 ft.-lbs./sec.	Metric, 75 kg-m/sec.				B. T. U., B.T.U./sec.	Calorie, kg-cal/sec.
1	7.23300	.0131509	.0133333	.0100000	.00980665	9.80665	.00929717	.00234329
0.138255	1	.00181818	.00184340	.00138255	.00135582	1.35582	.00128538	.(3)323971
76.0404	550.000	1	1.013872	.760404	.74570	745.70	.706959	.178184
75.0000	542.475	.986318	1	.750000	.735497	735.497	.697286	.175746
100.0000	723.300	1.315091	1.33333	1	.980665	980.665	.929715	.234328
101.9718	737.562	1.341022	1.359624	1.019718	1	1000.000	.948047	.238949
.1019718	.737562	.00134102	.00135962	.00101972	.00100000	1	.(3)948047	.(3)238949
107.5599	777.980	1.414510	1.434132	1.075599	1.0548	1054.80	1	.252043
426.7521	3086.70	5.61218	5.69003	4.26752	4.18500	4185.00	3.96758	1

VELOCITIES AND ACCELERATIONS

1 kine = 1 centimeter per second = 0.0328083 foot per second.
 1 radian per second = 57.2958 degrees per sec. = 0.159155 revolutions per sec.
 1 gravity = 980.665 centimeters per sec. per sec. = 32.1740 feet per sec. per sec.

Meters per Second, m/sec.	Feet per Second, ft./sec.	Miles per Hour, M/h	Knots U. S.	Kilometers per Hour, km/h	Meter per Sec. per Sec. m/sec./sec.	Feet per Sec. per Sec. ft./sec./sec.	Miles per Hour per Sec. M/h/sec.	Kilometers per Hour per Sec. km/h/sec.
1	3.28083	2.23693	1.94254	3.6	-----	-----	-----	-----
0.30480	1	0.68182	0.59209	1.09728	-----	-----	-----	-----
0.44704	1.46667	1	0.86839	1.60935	-----	-----	-----	-----
0.51479	1.68894	1.15155	1	1.85325	-----	-----	-----	-----
0.27778	0.91134	0.62137	0.53959	1	-----	-----	-----	-----
-----	-----	-----	-----	-----	1	3.28083	2.23693	3.6
-----	-----	-----	-----	-----	0.30480	1	0.68182	1.09728
-----	-----	-----	-----	-----	0.44704	1.46667	1	1.60935
-----	-----	-----	-----	-----	0.27778	0.91134	0.62137	1

NOTES:—

1 Electrical H. P. = 746.00 watts. But 1 H.P. of 550 ft.-lbs./per sec. = 745.70 watts when $g = 980.665 \text{ cm/sec}^2$.
 1 Watt = 1 Joule/sec. = $10^7 \text{ ergs/sec} = 10^7 \text{ dyne-cm/sec} = 3.4130 \text{ B.T.U. per hour} = 23895 \text{ cal}_{15}^\circ \text{ per sec}$.
 1 B.T.U. mean = $1054.8 \text{ joules} = 777.98 \text{ ft. lbs.} = 1/180 \text{ of heat required to raise 1 lb. water from } 32^\circ \text{ to } 212^\circ \text{ F}$.
 Based on International Critical Tables values. 1 Cal.₁₅^o = 4185 joules = 1000 cal.₁₅^o.

Notation:.(5) = .00000. For example, .(7)232 = .0000000232

TABLES FOR CONVERTING UNITED STATES WEIGHTS AND MEASURES

CUSTOMARY TO METRIC

WEIGHTS

No.	Grains to Milligrams	Troy Ounces to Grams	Avoirdupois Ounces to Grams	Avoirdupois Pounds to Kilograms	Net Tons of 2000 Pounds to Metric Tons	Gross Tons of 2240 Pounds to Metric Tons
1	64.79892	31.10348	28.34953	.45359	.90718	1.01605
2	129.59784	62.20696	56.69905	.90718	1.81437	2.03209
3	194.39675	93.31044	85.04858	1.36078	2.72155	3.04814
4	259.19567	124.41392	113.39811	1.81437	3.62874	4.06419
5	323.99459	155.51740	141.74763	2.26796	4.53592	5.08024
6	388.79351	186.62088	170.09716	2.72155	5.44311	6.09628
7	453.59243	217.72437	198.44669	3.17515	6.35029	7.11233
8	518.39135	248.82785	226.79621	3.62874	7.25748	8.12838
9	583.19026	279.93133	255.14574	4.08233	8.16466	9.14442

1 Avoirdupois Pound = 453.5924277 Grams

LINEAR MEASURE

No.	64ths of an Inch to Millimeters	Inches to Centimeters	Feet to Meters	Yards to Meters	Statute Miles to Kilometers	Nautical Miles to Kilometers
1	.39688	2.54001	.304801	.914402	1.60935	1.85325
2	.79375	5.08001	.609601	1.828804	3.21869	3.70650
3	1.19063	7.62002	.914402	2.743205	4.82804	5.55975
4	1.58750	10.16002	1.219202	3.657607	6.43739	7.41299
5	1.98438	12.70003	1.524003	4.572009	8.04674	9.26624
6	2.38125	15.24003	1.828804	5.486411	9.65608	11.11949
7	2.77813	17.78004	2.133604	6.400813	11.26543	12.97274
8	3.17501	20.32004	2.438405	7.315215	12.87478	14.82599
9	3.57188	22.86005	2.743205	8.229616	14.48412	16.67924

1 Nautical Mile = 1853.25 Meters
 1 Gunter's Chain = 20.1168 Meters
 1 Fathom = 1.82880 Meters

SQUARE MEASURE

No.	Square Inches to Square Centimeters	Square Feet to Square Meters	Square Yards to Square Meters	Acres to Hectares	Square Miles to Square Kilometers
1	6.45163	.092903	.83613	.40469	2.59000
2	12.90325	.185807	1.67226	.80937	5.18000
3	19.35488	.278710	2.50839	1.21406	7.77000
4	25.80650	.371614	3.34452	1.61875	10.35999
5	32.25813	.464517	4.18065	2.02344	12.94999
6	38.70975	.557420	5.01678	2.42812	15.53999
7	45.16138	.650324	5.85291	2.83281	18.12999
8	51.61300	.743227	6.68905	3.23750	20.71999
9	58.06463	.836131	7.52518	3.64219	23.30999

1 Square Statute Mile = 259.000 Hectares

TABLES FOR CONVERTING UNITED STATES WEIGHTS AND MEASURES

METRIC TO CUSTOMARY

WEIGHTS

No.	Milligrams to Grains	Grams to Troy Ounces	Grams to Avoirdupois Ounces	Kilograms to Avoirdupois Pounds	Tonnes to Net Tons of 2000 Pounds	Tonnes to Gross Tons of 2240 Pounds
1	.015432	.032151	.035274	2.20462	1.10231	.98421
2	.030865	.064301	.070548	4.40924	2.20462	1.96841
3	.046297	.096452	.105822	6.61387	3.30693	2.95262
4	.061729	.128603	.141096	8.81849	4.40924	3.93682
5	.077162	.160754	.176370	11.02311	5.51156	4.92103
6	.092594	.192904	.211644	13.22773	6.61387	5.90524
7	.108020	.225055	.246918	15.43236	7.71618	6.88944
8	.123459	.257206	.282192	17.63698	8.81849	7.87365
9	.138891	.289357	.317466	19.84160	9.92080	8.85785

1 Kilogram = 15432.35639 Grains

LINEAR MEASURE

No.	Millimeters to 64ths of an Inch	Centimeters to Inches	Meters to Feet	Meters to Yards	Kilometers to Statute Miles	Kilometers to Nautical Miles
1	2.51968	.39370	3.280833	1.093611	.62137	.53959
2	5.03936	.78740	6.561667	2.187222	1.24274	1.07918
3	7.55904	1.18110	9.842500	3.280833	1.86411	1.61878
4	10.07872	1.57480	13.123333	4.374444	2.48548	2.15837
5	12.59840	1.96850	16.404167	5.468056	3.10685	2.69796
6	15.11808	2.36220	19.685000	6.561667	3.72822	3.23755
7	17.63776	2.75590	22.965833	7.655278	4.34959	3.77714
8	20.15744	3.14960	26.246667	8.748889	4.97096	4.31674
9	22.67712	3.54330	29.527500	9.842500	5.59233	4.85633

1 Meter = .000539592 Nautical Mile
 = .0497097 Gunter's Chain
 = .546807 Fathom

SQUARE MEASURE

No.	Square Centimeters to Square Inches	Square Meters to Square Feet	Square Meters to Square Yards	Hectares to Acres	Square Kilometers to Square Miles
1	.15500	10.76387	1.19599	2.47104	.38610
2	.31000	21.52773	2.39197	4.94209	.77220
3	.46500	32.29160	3.58796	7.41313	1.15830
4	.62000	43.05547	4.78394	9.88418	1.54440
5	.77500	53.81934	5.97993	12.35522	1.93050
6	.93000	64.58320	7.17591	14.82626	2.31660
7	1.08500	75.34707	8.37190	17.29731	2.70270
8	1.24000	86.11094	9.56788	19.76835	3.08880
9	1.39500	96.87481	10.76387	22.23940	3.47490

1 Hectare = .00386101 Square Statute Mile

TABLES FOR CONVERTING UNITED STATES WEIGHTS AND MEASURES

CUSTOMARY TO METRIC

CUBIC MEASURE

No.	Cubic Inches to Cubic Centimeters	Cubic Inches to Cubic Decimeters	Cubic Feet to Cubic Meters	Cubic Yards to Cubic Meters
1	16.38716	.016387	.028317	.76456
2	32.77432	.032774	.056634	1.52912
3	49.16148	.049161	.084951	2.29368
4	65.54864	.065549	.113268	3.05824
5	81.93580	.081936	.141585	3.82280
6	98.32296	.098323	.169902	4.58736
7	114.71013	.114710	.198219	5.35192
8	131.09729	.131097	.226536	6.11648
9	147.48445	.147484	.254853	6.88104

CAPACITY MEASURES

No.	Liquid Quarts to Liters	Gallons to Liters	Gallons to Cubic Meters	Bushels to Hectoliters	Fluid Drams to Milliliters or Cubic Centimeters	Fluid Ounces to Milliliters or Cubic Centimeters
1	.94636	3.78543	.0037854	.35239	3.69671	29.57371
2	1.89272	7.57087	.0075709	.70479	7.39343	59.14741
3	2.83908	11.35630	.0113563	1.05718	11.09014	88.72112
4	3.78543	15.14174	.0151417	1.40957	14.78685	118.29483
5	4.73179	18.92717	.0189272	1.76196	18.48357	147.86854
6	5.67815	22.71261	.0227126	2.11436	22.18028	177.44224
7	6.62451	26.49804	.0264980	2.46675	25.87699	207.01595
8	7.57087	30.28348	.0302835	2.81914	29.57371	236.58966
9	8.51723	34.06891	.0340689	3.17154	33.27042	266.16336

MISCELLANEOUS

No.	Pounds per Linear Foot to Kilograms per Linear Meter	Pounds per Square Inch to Kilograms per Square Centimeter	Pounds per Square Foot to Kilograms per Square Meter	Pounds per Cubic Foot to Kilograms per Cubic Meter	Foot-Pounds to Kilogram- Meters	United States Horsepower to Metric Horsepower
1	1.48816	.070307	4.88241	16.01837	.13826	1.01387
2	2.97632	.140613	9.76482	32.03674	.27651	2.02774
3	4.46448	.210920	14.64723	48.05511	.41477	3.04162
4	5.95264	.281227	19.52963	64.07348	.55302	4.05549
5	7.44081	.351533	24.41204	80.09185	.69128	5.06936
6	8.92897	.421840	29.29445	96.11021	.82953	6.08323
7	10.41713	.492147	34.17686	112.12858	.96779	7.09710
8	11.90529	.562454	39.05927	128.14695	1.10604	8.11097
9	13.39345	.632760	43.94168	144.16532	1.24430	9.12485

TABLES FOR CONVERTING UNITED STATES WEIGHTS AND MEASURES

METRIC TO CUSTOMARY

CUBIC MEASURE

No.	Cubic Centimeters to Cubic Inches	Cubic Decimeters to Cubic Inches	Cubic Meters to Cubic Feet	Cubic Meters to Cubic Yards
1	.061023	61.02338	35.31445	1.30794
2	.122047	122.04676	70.62891	2.61589
3	.183070	183.07013	105.94336	3.92383
4	.244094	244.09351	141.25782	5.23177
5	.305117	305.11689	176.57227	6.53971
6	.366140	366.14027	211.88673	7.84766
7	.427164	427.16365	247.20118	9.15560
8	.488187	488.18702	282.51564	10.46354
9	.549210	549.21040	317.83009	11.77149

CAPACITY MEASURES

No.	Liters to Fluid Quarts	Liters to Gallons	Cubic Meters to Gallons	Hectoliters to Bushels	Milliliters or Cubic Centi- meters to Fluid Drams	Milliliters or Cubic Centi- meters to Fluid Ounces
1	1.05668	.26417	264.17047	2.83774	.27051	.033814
2	2.11336	.52834	528.34093	5.67548	.54102	.067628
3	3.17005	.79251	792.51140	8.51323	.81153	.101441
4	4.22673	1.05668	1056.68187	11.35097	1.08204	.135255
5	5.28341	1.32085	1320.85234	14.18871	1.35255	.169069
6	6.34009	1.58502	1585.02280	17.02645	1.62306	.202883
7	7.39677	1.84919	1849.19327	19.86420	1.89357	.236697
8	8.45345	2.11336	2113.36374	22.70194	2.16408	.270510
9	9.51014	2.37753	2377.53420	25.53968	2.43460	.304324

MISCELLANEOUS

No.	Kilograms per Linear Meter to Pounds per Linear Foot	Kilograms per Square Centimeter to Pounds per Square Inch	Kilograms per Square Meter to Pounds per Square Foot	Kilograms per Cubic Meter to Pounds per Cubic Foot	Kilogram- Meters to Foot-Pounds	Metric Horsepower to United States Horsepower
1	.67197	14.22340	.20482	.062428	7.23300	.98632
2	1.34394	28.44680	.40963	.124857	14.46600	1.97264
3	2.01591	42.67020	.61445	.187285	21.69900	2.95895
4	2.68788	56.89359	.81927	.249713	28.93200	3.94527
5	3.35985	71.11699	1.02408	.312142	36.16500	4.93159
6	4.03182	85.34039	1.22890	.374570	43.39799	5.91791
7	4.70379	99.56379	1.43372	.436998	50.63099	6.90423
8	5.37576	113.78718	1.63854	.499427	57.86399	7.89054
9	6.04773	128.01058	1.84335	.561855	65.09699	8.87686

EQUIVALENTS OF MILLIMETERS IN INCHES

CONVERSION FACTOR: 1 MILLIMETER = .03937 INCH

Milli- meters	0	100	200	300	400	500	600	700	800	900	Milli- meters
0	.000	3.937	7.874	11.811	15.748	19.685	23.622	27.559	31.496	35.433	0
1	.039	3.976	7.913	11.850	15.787	19.724	23.661	27.598	31.535	35.472	1
2	.079	4.016	7.953	11.890	15.827	19.764	23.701	27.638	31.575	35.512	2
3	.118	4.055	7.992	11.929	15.866	19.803	23.740	27.677	31.614	35.551	3
4	.157	4.094	8.031	11.968	15.905	19.842	23.779	27.716	31.653	35.590	4
5	.197	4.134	8.071	12.008	15.945	19.882	23.819	27.756	31.693	35.630	5
6	.236	4.173	8.110	12.047	15.984	19.921	23.858	27.795	31.732	35.669	6
7	.276	4.213	8.150	12.087	16.024	19.961	23.898	27.835	31.772	35.709	7
8	.315	4.252	8.189	12.126	16.063	20.000	23.937	27.874	31.811	35.748	8
9	.354	4.291	8.228	12.165	16.102	20.039	23.976	27.913	31.850	35.787	9
10	.394	4.331	8.268	12.205	16.142	20.079	24.016	27.953	31.890	35.827	10
11	.433	4.370	8.307	12.244	16.181	20.118	24.055	27.992	31.929	35.866	11
12	.472	4.409	8.346	12.283	16.220	20.157	24.094	28.031	31.968	35.905	12
13	.512	4.449	8.386	12.323	16.260	20.197	24.134	28.071	32.008	35.945	13
14	.551	4.488	8.425	12.362	16.299	20.236	24.173	28.110	32.047	35.984	14
15	.591	4.528	8.465	12.402	16.339	20.276	24.213	28.150	32.087	36.024	15
16	.630	4.567	8.504	12.441	16.378	20.315	24.252	28.189	32.126	36.063	16
17	.669	4.606	8.543	12.480	16.417	20.354	24.291	28.228	32.165	36.102	17
18	.709	4.646	8.583	12.520	16.457	20.394	24.331	28.268	32.205	36.142	18
19	.748	4.685	8.622	12.559	16.496	20.433	24.370	28.307	32.244	36.181	19
20	.787	4.724	8.661	12.598	16.535	20.472	24.409	28.346	32.283	36.220	20
21	.827	4.764	8.701	12.638	16.575	20.512	24.449	28.386	32.323	36.260	21
22	.866	4.803	8.740	12.677	16.614	20.551	24.488	28.425	32.362	36.299	22
23	.906	4.843	8.780	12.717	16.654	20.591	24.528	28.465	32.402	36.339	23
24	.945	4.882	8.819	12.756	16.693	20.630	24.567	28.504	32.441	36.378	24
25	.984	4.921	8.858	12.795	16.732	20.669	24.606	28.543	32.480	36.417	25
26	1.024	4.961	8.898	12.835	16.772	20.709	24.646	28.583	32.520	36.457	26
27	1.063	5.000	8.937	12.874	16.811	20.748	24.685	28.622	32.559	36.496	27
28	1.102	5.039	8.976	12.913	16.850	20.787	24.724	28.661	32.598	36.535	28
29	1.142	5.079	9.016	12.953	16.890	20.827	24.764	28.701	32.638	36.575	29
30	1.181	5.118	9.055	12.992	16.929	20.866	24.803	28.740	32.677	36.614	30
31	1.220	5.157	9.094	13.031	16.968	20.905	24.842	28.779	32.716	36.653	31
32	1.260	5.197	9.134	13.071	17.008	20.945	24.882	28.819	32.756	36.693	32
33	1.299	5.236	9.173	13.110	17.047	20.984	24.921	28.858	32.795	36.732	33
34	1.339	5.276	9.213	13.150	17.087	21.024	24.961	28.898	32.835	36.772	34
35	1.378	5.315	9.252	13.189	17.126	21.063	25.000	28.937	32.874	36.811	35
36	1.417	5.354	9.291	13.228	17.165	21.102	25.039	28.976	32.913	36.850	36
37	1.457	5.394	9.331	13.268	17.205	21.142	25.079	29.016	32.953	36.890	37
38	1.496	5.433	9.370	13.307	17.244	21.181	25.118	29.055	32.992	36.929	38
39	1.535	5.472	9.409	13.346	17.283	21.220	25.157	29.094	33.031	36.968	39
40	1.575	5.512	9.449	13.386	17.323	21.260	25.197	29.134	33.071	37.008	40
41	1.614	5.551	9.488	13.425	17.362	21.299	25.236	29.173	33.110	37.047	41
42	1.654	5.591	9.528	13.465	17.402	21.339	25.276	29.213	33.150	37.087	42
43	1.693	5.630	9.567	13.504	17.441	21.378	25.315	29.252	33.189	37.126	43
44	1.732	5.669	9.606	13.543	17.480	21.417	25.354	29.291	33.228	37.165	44
45	1.772	5.709	9.646	13.583	17.520	21.457	25.394	29.331	33.268	37.205	45
46	1.811	5.748	9.685	13.622	17.559	21.496	25.433	29.370	33.307	37.244	46
47	1.850	5.787	9.724	13.661	17.598	21.535	25.472	29.409	33.346	37.283	47
48	1.890	5.827	9.764	13.701	17.638	21.575	25.512	29.449	33.386	37.323	48
49	1.929	5.866	9.803	13.740	17.677	21.614	25.551	29.488	33.425	37.362	49

EQUIVALENTS OF MILLIMETERS IN INCHES

CONVERSION FACTOR: 1 MILLIMETER = .03937 INCH

Milli- meters	0	100	200	300	400	500	600	700	800	900	Milli- meters
50	1.969	5.906	9.843	13.780	17.717	21.654	25.591	29.528	33.465	37.402	50
51	2.008	5.945	9.882	13.819	17.756	21.693	25.630	29.567	33.504	37.441	51
52	2.047	5.984	9.921	13.858	17.795	21.732	25.669	29.606	33.543	37.480	52
53	2.087	6.024	9.961	13.898	17.835	21.772	25.709	29.646	33.583	37.520	53
54	2.126	6.063	10.000	13.937	17.874	21.811	25.748	29.685	33.622	37.559	54
55	2.165	6.102	10.039	13.976	17.913	21.850	25.787	29.724	33.661	37.598	55
56	2.205	6.142	10.079	14.016	17.953	21.890	25.827	29.764	33.701	37.638	56
57	2.244	6.181	10.118	14.055	17.992	21.929	25.866	29.803	33.740	37.677	57
58	2.283	6.220	10.157	14.094	18.031	21.968	25.905	29.842	33.779	37.716	58
59	2.323	6.260	10.197	14.134	18.071	22.008	25.945	29.882	33.819	37.756	59
60	2.362	6.299	10.236	14.173	18.110	22.047	25.984	29.921	33.858	37.795	60
61	2.402	6.339	10.276	14.213	18.150	22.087	26.024	29.961	33.898	37.835	61
62	2.441	6.378	10.315	14.252	18.189	22.126	26.063	30.000	33.937	37.874	62
63	2.480	6.417	10.354	14.291	18.228	22.165	26.102	30.039	33.976	37.913	63
64	2.520	6.457	10.394	14.331	18.268	22.205	26.142	30.079	34.016	37.953	64
65	2.559	6.496	10.433	14.370	18.307	22.244	26.181	30.118	34.055	37.992	65
66	2.598	6.535	10.472	14.409	18.346	22.283	26.220	30.157	34.094	38.031	66
67	2.638	6.575	10.512	14.449	18.386	22.323	26.260	30.197	34.134	38.071	67
68	2.677	6.614	10.551	14.488	18.425	22.362	26.299	30.236	34.173	38.110	68
69	2.717	6.654	10.591	14.528	18.465	22.402	26.339	30.276	34.213	38.150	69
70	2.756	6.693	10.630	14.567	18.504	22.441	26.378	30.315	34.252	38.189	70
71	2.795	6.732	10.669	14.606	18.543	22.480	26.417	30.354	34.291	38.228	71
72	2.835	6.772	10.709	14.646	18.583	22.520	26.457	30.394	34.331	38.268	72
73	2.874	6.811	10.748	14.685	18.622	22.559	26.496	30.433	34.370	38.307	73
74	2.913	6.850	10.787	14.724	18.661	22.598	26.535	30.472	34.409	38.346	74
75	2.953	6.890	10.827	14.764	18.701	22.638	26.575	30.512	34.449	38.386	75
76	2.992	6.929	10.866	14.803	18.740	22.677	26.614	30.551	34.488	38.425	76
77	3.031	6.968	10.905	14.842	18.779	22.716	26.653	30.590	34.527	38.464	77
78	3.071	7.008	10.945	14.882	18.819	22.756	26.693	30.630	34.567	38.504	78
79	3.110	7.047	10.984	14.921	18.858	22.795	26.732	30.669	34.606	38.543	79
80	3.150	7.087	11.024	14.961	18.898	22.835	26.772	30.709	34.646	38.583	80
81	3.189	7.126	11.063	15.000	18.937	22.874	26.811	30.748	34.685	38.622	81
82	3.228	7.165	11.102	15.039	18.976	22.913	26.850	30.787	34.724	38.661	82
83	3.268	7.205	11.142	15.079	19.016	22.953	26.890	30.827	34.764	38.701	83
84	3.307	7.244	11.181	15.118	19.055	22.992	26.929	30.866	34.803	38.740	84
85	3.346	7.283	11.220	15.157	19.094	23.031	26.968	30.905	34.842	38.779	85
86	3.386	7.323	11.260	15.197	19.134	23.071	27.008	30.945	34.882	38.819	86
87	3.425	7.362	11.299	15.236	19.173	23.110	27.047	30.984	34.921	38.858	87
88	3.465	7.402	11.339	15.276	19.213	23.150	27.087	31.024	34.961	38.898	88
89	3.504	7.441	11.378	15.315	19.252	23.189	27.126	31.063	35.000	38.937	89
90	3.543	7.480	11.417	15.354	19.291	23.228	27.165	31.102	35.039	38.976	90
91	3.583	7.520	11.457	15.394	19.331	23.268	27.205	31.142	35.079	39.016	91
92	3.622	7.559	11.496	15.433	19.370	23.307	27.244	31.181	35.118	39.055	92
93	3.661	7.598	11.535	15.472	19.409	23.346	27.283	31.220	35.157	39.094	93
94	3.701	7.638	11.575	15.512	19.449	23.386	27.323	31.260	35.197	39.134	94
95	3.740	7.677	11.614	15.551	19.488	23.425	27.362	31.299	35.236	39.173	95
96	3.780	7.717	11.654	15.591	19.528	23.465	27.402	31.339	35.276	39.213	96
97	3.819	7.756	11.693	15.630	19.567	23.504	27.441	31.378	35.315	39.252	97
98	3.858	7.795	11.732	15.669	19.606	23.543	27.480	31.417	35.354	39.291	98
99	3.898	7.835	11.772	15.709	19.646	23.583	27.520	31.457	35.394	39.331	99

EQUIVALENTS OF METERS IN FEET

Conversion factor: 1 meter = 3.280833333 feet

Meters	0	100	200	300	400	500	600	700	800	900	Meters
0		328.0833	656.1667	984.250	1,312.333	1,640.417	1,968.500	2,296.583	2,624.667	2,952.750	0
1	3.2808	331.3642	659.4475	987.531	1,315.614	1,643.698	1,971.781	2,299.864	2,627.948	2,956.031	1
2	6.5617	334.6450	662.7283	990.812	1,318.895	1,646.978	1,975.062	2,303.145	2,631.228	2,959.312	2
3	9.8425	337.9258	666.0092	994.093	1,322.176	1,650.259	1,978.343	2,306.426	2,634.509	2,962.593	3
4	13.1233	341.2067	669.2900	997.373	1,325.457	1,653.540	1,981.623	2,309.707	2,637.790	2,965.873	4
5	16.4042	344.4875	672.5708	1,000.654	1,328.738	1,656.821	1,984.904	2,312.988	2,641.071	2,969.154	5
6	19.6850	347.7683	675.8517	1,003.935	1,332.018	1,660.102	1,988.185	2,316.268	2,644.352	2,972.435	6
7	22.9658	351.0492	679.1325	1,007.216	1,335.299	1,663.383	1,991.466	2,319.549	2,647.633	2,975.716	7
8	26.2467	354.3300	682.4133	1,010.497	1,338.580	1,666.663	1,994.747	2,322.830	2,650.913	2,978.997	8
9	29.5275	357.6108	685.6942	1,013.778	1,341.861	1,669.944	1,998.028	2,326.111	2,654.194	2,982.278	9
10	32.8083	360.8917	688.9750	1,017.058	1,345.142	1,673.225	2,001.308	2,329.392	2,657.475	2,985.558	10
11	36.0892	364.1725	692.2558	1,020.339	1,348.423	1,676.506	2,004.589	2,332.673	2,660.756	2,988.839	11
12	39.3700	367.4533	695.5367	1,023.620	1,351.703	1,679.787	2,007.870	2,335.953	2,664.037	2,992.120	12
13	42.6508	370.7342	698.8175	1,026.901	1,354.984	1,683.068	2,011.151	2,339.234	2,667.318	2,995.401	13
14	45.9317	374.0150	702.0983	1,030.182	1,358.265	1,686.348	2,014.432	2,342.515	2,670.598	2,998.682	14
15	49.2125	377.2958	705.3792	1,033.463	1,361.546	1,689.629	2,017.713	2,345.796	2,673.879	3,001.963	15
16	52.4933	380.5767	708.6600	1,036.743	1,364.827	1,692.910	2,020.993	2,349.077	2,677.160	3,005.243	16
17	55.7742	383.8575	711.9408	1,040.024	1,368.108	1,696.191	2,024.274	2,352.358	2,680.441	3,008.524	17
18	59.0550	387.1383	715.2217	1,043.305	1,371.388	1,699.472	2,027.555	2,355.638	2,683.722	3,011.805	18
19	62.3358	390.4192	718.5025	1,046.586	1,374.669	1,702.753	2,030.836	2,358.919	2,687.003	3,015.086	19
20	65.6167	393.7000	721.7833	1,049.867	1,377.950	1,706.033	2,034.117	2,362.200	2,690.283	3,018.367	20
21	68.8975	396.9808	725.0642	1,053.148	1,381.231	1,709.314	2,037.398	2,365.481	2,693.564	3,021.648	21
22	72.1783	400.2617	728.3450	1,056.428	1,384.512	1,712.595	2,040.678	2,368.762	2,696.845	3,024.928	22
23	75.4592	403.5425	731.6258	1,059.709	1,387.793	1,715.876	2,043.959	2,372.043	2,700.126	3,028.209	23
24	78.7400	406.8233	734.9067	1,062.990	1,391.073	1,719.157	2,047.240	2,375.323	2,703.407	3,031.490	24
25	82.0208	410.1042	738.1875	1,066.271	1,394.354	1,722.438	2,050.521	2,378.604	2,706.688	3,034.771	25
26	85.3017	413.3850	741.4683	1,069.552	1,397.635	1,725.718	2,053.802	2,381.885	2,709.968	3,038.052	26
27	88.5825	416.6658	744.7492	1,072.833	1,400.916	1,728.999	2,057.083	2,385.166	2,713.249	3,041.333	27
28	91.8633	419.9467	748.0300	1,076.113	1,404.197	1,732.280	2,060.363	2,388.447	2,716.530	3,044.613	28
29	95.1442	423.2275	751.3108	1,079.394	1,407.478	1,735.561	2,063.644	2,391.728	2,719.811	3,047.894	29
30	98.4250	426.5083	754.5917	1,082.675	1,410.758	1,738.842	2,066.925	2,395.008	2,723.092	3,051.175	30
31	101.7058	429.7892	757.8725	1,085.956	1,414.039	1,742.123	2,070.206	2,398.289	2,726.373	3,054.456	31
32	104.9867	433.0700	761.1533	1,089.237	1,417.320	1,745.403	2,073.487	2,401.570	2,729.653	3,057.737	32
33	108.2675	436.3508	764.4342	1,092.518	1,420.601	1,748.684	2,076.768	2,404.851	2,732.934	3,061.018	33
34	111.5483	439.6317	767.7150	1,095.798	1,423.882	1,751.965	2,080.048	2,408.132	2,736.215	3,064.298	34
35	114.8292	442.9125	770.9958	1,099.079	1,427.163	1,755.246	2,083.329	2,411.413	2,739.496	3,067.579	35
36	118.1100	446.1933	774.2767	1,102.360	1,430.443	1,758.527	2,086.610	2,414.693	2,742.777	3,070.860	36
37	121.3908	449.4742	777.5575	1,105.641	1,433.724	1,761.808	2,089.891	2,417.974	2,746.058	3,074.141	37
38	124.6717	452.7550	780.8383	1,108.922	1,437.005	1,765.088	2,093.172	2,421.255	2,749.338	3,077.422	38
39	127.9525	456.0358	784.1192	1,112.203	1,440.286	1,768.369	2,096.453	2,424.536	2,752.619	3,080.703	39
40	131.2333	459.3167	787.4000	1,115.483	1,443.567	1,771.650	2,099.733	2,427.817	2,755.900	3,083.983	40
41	134.5142	462.5975	790.6808	1,118.764	1,446.848	1,774.931	2,103.014	2,431.098	2,759.181	3,087.264	41
42	137.7950	465.8783	793.9617	1,122.045	1,450.128	1,778.212	2,106.295	2,434.378	2,762.462	3,090.545	42
43	141.0758	469.1592	797.2425	1,125.326	1,453.409	1,781.493	2,109.576	2,437.659	2,765.743	3,093.826	43
44	144.3567	472.4400	800.5233	1,128.607	1,456.690	1,784.773	2,112.857	2,440.940	2,769.023	3,097.107	44
45	147.6375	475.7208	803.8042	1,131.888	1,459.971	1,788.054	2,116.138	2,444.221	2,772.304	3,100.388	45
46	150.9183	479.0017	807.0850	1,135.168	1,463.252	1,791.335	2,119.418	2,447.502	2,775.585	3,103.668	46
47	154.1992	482.2825	810.3658	1,138.449	1,466.533	1,794.616	2,122.699	2,450.783	2,778.866	3,106.949	47
48	157.4800	485.5633	813.6467	1,141.730	1,469.813	1,797.897	2,125.980	2,454.063	2,782.147	3,110.230	48
49	160.7608	488.8442	816.9275	1,145.011	1,473.094	1,801.178	2,129.261	2,457.344	2,785.428	3,113.511	49

For feet and inches, use Decimals of a Foot table, p. 355.

For example, 647 meters = 2122.699 ft. = 2122 ft. 8 $\frac{3}{4}$ in.

EQUIVALENTS OF METERS IN FEET

Conversion factor: 1 meter = 3.28083333 feet

Meters	0	100	200	300	400	500	600	700	800	900	Meters
50	164.0417	492.1250	820.2083	1,148.292	1,476.375	1,804.458	2,132.542	2,460.625	2,788.708	3,116.792	50
51	167.3225	495.4058	823.4892	1,151.573	1,479.656	1,807.739	2,135.823	2,463.906	2,791.989	3,120.073	51
52	170.6033	498.6867	826.7700	1,154.853	1,482.937	1,811.020	2,139.103	2,467.187	2,795.270	3,123.353	52
53	173.8842	501.9675	830.0508	1,158.134	1,486.218	1,814.301	2,142.384	2,470.468	2,798.551	3,126.634	53
54	177.1650	505.2483	833.3317	1,161.415	1,489.498	1,817.582	2,145.665	2,473.748	2,801.832	3,129.915	54
55	180.4458	508.5292	836.6125	1,164.696	1,492.779	1,820.863	2,148.946	2,477.029	2,805.113	3,133.196	55
56	183.7267	511.8100	839.8933	1,167.977	1,496.060	1,824.143	2,152.227	2,480.310	2,808.393	3,136.477	56
57	187.0075	515.0908	843.1742	1,171.258	1,499.341	1,827.424	2,155.508	2,483.591	2,811.674	3,139.758	57
58	190.2883	518.3717	846.4550	1,174.538	1,502.622	1,830.705	2,158.788	2,486.872	2,814.955	3,143.038	58
59	193.5692	521.6525	849.7358	1,177.819	1,505.903	1,833.986	2,162.069	2,490.153	2,818.236	3,146.319	59
60	196.8500	524.9333	853.0167	1,181.100	1,509.183	1,837.267	2,165.350	2,493.433	2,821.517	3,149.600	60
61	200.1308	528.2142	856.2975	1,184.381	1,512.464	1,840.548	2,168.631	2,496.714	2,824.798	3,152.881	61
62	203.4117	531.4950	859.5783	1,187.662	1,515.745	1,843.828	2,171.912	2,499.995	2,828.078	3,156.162	62
63	206.6925	534.7758	862.8592	1,190.943	1,519.026	1,847.109	2,175.193	2,503.276	2,831.359	3,159.443	63
64	209.9733	538.0567	866.1400	1,194.223	1,522.307	1,850.390	2,178.473	2,506.557	2,834.640	3,162.723	64
65	213.2542	541.3375	869.4208	1,197.504	1,525.588	1,853.671	2,181.754	2,509.838	2,837.921	3,166.004	65
66	216.5350	544.6183	872.7017	1,200.785	1,528.868	1,856.952	2,185.035	2,513.118	2,841.202	3,169.285	66
67	219.8158	547.8992	875.9825	1,204.066	1,532.149	1,860.233	2,188.316	2,516.399	2,844.483	3,172.566	67
68	223.0967	551.1800	879.2633	1,207.347	1,535.430	1,863.513	2,191.597	2,519.680	2,847.763	3,175.847	68
69	226.3775	554.4608	882.5442	1,210.628	1,538.711	1,866.794	2,194.878	2,522.961	2,851.044	3,179.128	69
70	229.6583	557.7417	885.8250	1,213.908	1,541.992	1,870.075	2,198.158	2,526.242	2,854.325	3,182.408	70
71	232.9392	561.0225	889.1058	1,217.189	1,545.273	1,873.356	2,201.439	2,529.523	2,857.606	3,185.689	71
72	236.2200	564.3033	892.3867	1,220.470	1,548.553	1,876.637	2,204.720	2,532.803	2,860.887	3,188.970	72
73	239.5008	567.5842	895.6675	1,223.751	1,551.834	1,879.918	2,208.001	2,536.084	2,864.168	3,192.251	73
74	242.7817	570.8650	898.9483	1,227.032	1,555.115	1,883.198	2,211.282	2,539.365	2,867.448	3,195.532	74
75	246.0625	574.1458	902.2292	1,230.313	1,558.396	1,886.479	2,214.563	2,542.646	2,870.729	3,198.813	75
76	249.3433	577.4267	905.5100	1,233.593	1,561.677	1,889.760	2,217.843	2,545.927	2,874.010	3,202.093	76
77	252.6242	580.7075	908.7908	1,236.874	1,564.958	1,893.041	2,221.124	2,549.208	2,877.291	3,205.374	77
78	255.9050	583.9883	912.0713	1,240.155	1,568.238	1,896.322	2,224.405	2,552.488	2,880.572	3,208.655	78
79	259.1858	587.2692	915.3525	1,243.436	1,571.519	1,899.603	2,227.686	2,555.769	2,883.853	3,211.936	79
80	262.4667	590.5500	918.6333	1,246.717	1,574.800	1,902.883	2,230.967	2,559.050	2,887.133	3,215.217	80
81	265.7475	593.8308	921.9142	1,249.998	1,578.081	1,906.164	2,234.248	2,562.331	2,890.414	3,218.498	81
82	269.0283	597.1117	925.1950	1,253.278	1,581.362	1,909.445	2,237.528	2,565.612	2,893.695	3,221.778	82
83	272.3092	600.3925	928.4758	1,256.559	1,584.643	1,912.726	2,240.809	2,568.893	2,896.976	3,225.059	83
84	275.5900	603.6733	931.7567	1,259.840	1,587.923	1,916.007	2,244.090	2,572.173	2,900.257	3,228.340	84
85	278.8708	606.9542	935.0375	1,263.121	1,591.204	1,919.288	2,247.371	2,575.454	2,903.538	3,231.621	85
86	282.1517	610.2350	938.3183	1,266.402	1,594.485	1,922.568	2,250.652	2,578.735	2,906.818	3,234.902	86
87	285.4325	613.5158	941.5992	1,269.683	1,597.766	1,925.849	2,253.933	2,582.016	2,910.099	3,238.183	87
88	288.7133	616.7967	944.8800	1,272.963	1,601.047	1,929.130	2,257.213	2,585.297	2,913.380	3,241.463	88
89	291.9942	620.0775	948.1608	1,276.244	1,604.328	1,932.411	2,260.494	2,588.578	2,916.661	3,244.744	89
90	295.2750	623.3583	951.4417	1,279.525	1,607.608	1,935.692	2,263.775	2,591.858	2,919.942	3,248.025	90
91	298.5558	626.6392	954.7225	1,282.806	1,610.889	1,938.973	2,267.056	2,595.139	2,923.223	3,251.306	91
92	301.8367	629.9200	958.0033	1,286.087	1,614.170	1,942.253	2,270.337	2,598.420	2,926.503	3,254.587	92
93	305.1175	633.2008	961.2842	1,289.368	1,617.451	1,945.534	2,273.618	2,601.701	2,929.784	3,257.868	93
94	308.3983	636.4817	964.5650	1,292.648	1,620.732	1,948.815	2,276.898	2,604.982	2,933.065	3,261.148	94
95	311.6792	639.7625	967.8458	1,295.929	1,624.013	1,952.096	2,280.179	2,608.263	2,936.346	3,264.429	95
96	314.9600	643.0433	971.1267	1,299.210	1,627.293	1,955.377	2,283.460	2,611.543	2,939.627	3,267.710	96
97	318.2408	646.3242	974.4075	1,302.491	1,630.574	1,958.658	2,286.741	2,614.824	2,942.908	3,270.991	97
98	321.5217	649.6050	977.6883	1,305.772	1,633.855	1,961.938	2,290.022	2,618.105	2,946.188	3,274.272	98
99	324.8025	652.8858	980.9692	1,309.053	1,637.136	1,965.219	2,293.303	2,621.386	2,949.469	3,277.553	99

For feet and inches, use Decimals of a Foot table, p. 355.
 For example, 381 meters = 1249.998 ft. = 1249 ft. 11 $\frac{11}{16}$ in.

EQUIVALENTS OF FEET IN METERS

Conversion factor: 1 foot = 0.3048006096 meter

Feet	0	100	200	300	400	500	600	700	800	900	Feet
0		30.48006	60.96012	91.4402	121.9202	152.4003	182.8804	213.3604	243.8405	274.3205	0
1	.30480	30.78486	61.26492	91.7450	122.2250	152.7051	183.1852	213.6652	244.1453	274.6253	1
2	.60960	31.08966	61.56972	92.0498	122.5298	153.0099	183.4900	213.9700	244.4501	274.9301	2
3	.91440	31.39446	61.87452	92.3546	122.8346	153.3147	183.7948	214.2748	244.7549	275.2350	3
4	1.21920	31.69926	62.17932	92.6594	123.1394	153.6195	184.0996	214.5796	245.0597	275.5398	4
5	1.52400	32.00406	62.48412	92.9642	123.4442	153.9243	184.4044	214.8844	245.3645	275.8446	5
6	1.82880	32.30886	62.78893	93.2690	123.7490	154.2291	184.7092	215.1892	245.6693	276.1494	6
7	2.13360	32.61367	63.09373	93.5738	124.0538	154.5339	185.0140	215.4940	245.9741	276.4545	7
8	2.43840	32.91847	63.39853	93.8786	124.3586	154.8387	185.3188	215.7988	246.2789	276.7590	8
9	2.74321	33.22327	63.70333	94.1834	124.6634	155.1435	185.6236	216.1036	246.5837	277.0638	9
10	3.04801	33.52807	64.00813	94.4882	124.9682	155.4483	185.9284	216.4084	246.8885	277.3686	10
11	3.35281	33.83287	64.31293	94.7930	125.2731	155.7531	186.2332	216.7132	247.1933	277.6734	11
12	3.65761	34.13767	64.61773	95.0978	125.5779	156.0579	186.5380	217.0180	247.4981	277.9782	12
13	3.96241	34.44247	64.92253	95.4026	125.8827	156.3627	186.8428	217.3228	247.8029	278.2830	13
14	4.26721	34.74727	65.22733	95.7074	126.1875	156.6675	187.1476	217.6276	248.1077	278.5878	14
15	4.57201	35.05207	65.53213	96.0122	126.4923	156.9723	187.4524	217.9324	248.4125	278.8926	15
16	4.87681	35.35687	65.83693	96.3170	126.7971	157.2771	187.7572	218.2372	248.7173	279.1974	16
17	5.18161	35.66167	66.14173	96.6218	127.1019	157.5819	188.0620	218.5420	249.0221	279.5022	17
18	5.48641	35.96647	66.44653	96.9266	127.4067	157.8867	188.3668	218.8468	249.3269	279.8070	18
19	5.79121	36.27127	66.75133	97.2314	127.7115	158.1915	188.6716	219.1516	249.6317	280.1118	19
20	6.09601	36.57607	67.05613	97.5362	128.0163	158.4963	188.9764	219.4564	249.9365	280.4166	20
21	6.40081	36.88087	67.36093	97.8410	128.3211	158.8011	189.2812	219.7612	250.2413	280.7214	21
22	6.70561	37.18567	67.66574	98.1458	128.6259	159.1059	189.5860	220.0660	250.5461	281.0262	22
23	7.01041	37.49047	67.97054	98.4506	128.9307	159.4107	189.8908	220.3708	250.8509	281.3310	23
24	7.31521	37.79527	68.27534	98.7554	129.2355	159.7155	190.1956	220.6756	251.1557	281.6358	24
25	7.62002	38.10008	68.58014	99.0602	129.5403	160.0203	190.5004	220.9804	251.4605	281.9406	25
26	7.92482	38.40488	68.88494	99.3650	129.8451	160.3251	190.8052	221.2852	251.7653	282.2454	26
27	8.22962	38.70968	69.18974	99.6698	130.1499	160.6299	191.1100	221.5900	252.0701	282.5502	27
28	8.53442	39.01448	69.49454	99.9746	130.4547	160.9347	191.4148	221.8948	252.3749	282.8550	28
29	8.83922	39.31928	69.79934	100.2794	130.7595	161.2395	191.7196	222.1996	252.6797	283.1598	29
30	9.14402	39.62408	70.10414	100.5842	131.0643	161.5443	192.0244	222.5044	252.9845	283.4646	30
31	9.44882	39.92888	70.40894	100.8890	131.3691	161.8491	192.3292	222.8092	253.2893	283.7694	31
32	9.75362	40.23368	70.71374	101.1938	131.6739	162.1539	192.6340	223.1140	253.5941	284.0742	32
33	10.05842	40.53848	71.01854	101.4986	131.9787	162.4587	192.9388	223.4188	253.8989	284.3790	33
34	10.36322	40.84328	71.32334	101.8034	132.2835	162.7635	193.2436	223.7236	254.2037	284.6838	34
35	10.66802	41.14808	71.62814	102.1082	132.5883	163.0683	193.5484	224.0284	254.5085	284.9886	35
36	10.97282	41.45288	71.93294	102.4130	132.8931	163.3731	193.8532	224.3332	254.8133	285.2934	36
37	11.27762	41.75768	72.23774	102.7178	133.1979	163.6779	194.1580	224.6380	255.1181	285.5982	37
38	11.58242	42.06248	72.54255	103.0226	133.5027	163.9827	194.4628	224.9428	255.4229	285.9030	38
39	11.88722	42.36728	72.84735	103.3274	133.8075	164.2875	194.7676	225.2477	255.7277	286.2078	39
40	12.19202	42.67209	73.15215	103.6322	134.1123	164.5923	195.0724	225.5525	256.0325	286.5126	40
41	12.49682	42.97689	73.45695	103.9370	134.4171	164.8971	195.3772	225.8573	256.3373	286.8174	41
42	12.80163	43.28169	73.76175	104.2418	134.7219	165.2019	195.6820	226.1621	256.6421	287.1222	42
43	13.10643	43.58649	74.06655	104.5466	135.0267	165.5067	195.9868	226.4669	256.9469	287.4270	43
44	13.41123	43.89129	74.37135	104.8514	135.3315	165.8115	196.2916	226.7717	257.2517	287.7318	44
45	13.71603	44.19609	74.67615	105.1562	135.6363	166.1163	196.5964	227.0765	257.5565	288.0366	45
46	14.02083	44.50089	74.98095	105.4610	135.9411	166.4211	196.9012	227.3813	257.8613	288.3414	46
47	14.32563	44.80569	75.28575	105.7658	136.2459	166.7259	197.2060	227.6861	258.1661	288.6462	47
48	14.63043	45.11049	75.59055	106.0706	136.5507	167.0307	197.5108	227.9909	258.4709	288.9510	48
49	14.93523	45.41529	75.89535	106.3754	136.8555	167.3355	197.8156	228.2957	258.7757	289.2558	49

When feet and inches and fractions are involved, use also Millimeter Equivalents to One Foot table, p. 314. For example, 723 ft. 9 $\frac{1}{4}$ in. = 220.3708 + .2373 = 220.6081 meters.

EQUIVALENTS OF FEET IN METERS

Conversion factor: 1 foot = 0.3048006096 meter

Feet	0	100	200	300	400	500	600	700	800	900	Feet
50	15.24003	45.72009	76.20015	106.6802	137.1603	167.6403	198.1204	228.6005	259.0805	289.5606	50
51	15.54483	46.02489	76.50495	106.9850	137.4651	167.9451	198.4252	228.9053	259.3853	289.8654	51
52	15.84963	46.32969	76.80975	107.2898	137.7699	168.2499	198.7300	229.2101	259.6901	290.1702	52
53	16.15443	46.63449	77.11455	107.5946	138.0747	168.5547	199.0348	229.5149	259.9949	290.4750	53
54	16.45923	46.93929	77.41935	107.8994	138.3795	168.8595	199.3396	229.8197	260.2997	290.7798	54
55	16.76403	47.24409	77.72416	108.2042	138.6843	169.1643	199.6444	230.1245	260.6045	291.0846	55
56	17.06883	47.54890	78.02896	108.5090	138.9891	169.4691	199.9492	230.4293	260.9093	291.3894	56
57	17.37363	47.85370	78.33376	108.8138	139.2939	169.7739	200.2540	230.7341	261.2141	291.6942	57
58	17.67843	48.15850	78.63856	109.1186	139.5987	170.0787	200.5588	231.0389	261.5189	291.9990	58
59	17.98324	48.46330	78.94336	109.4234	139.9035	170.3835	200.8636	231.3437	261.8237	292.3038	59
60	18.28804	48.76810	79.24816	109.7282	140.2083	170.6883	201.1684	231.6485	262.1285	292.6086	60
61	18.59284	49.07290	79.55296	110.0330	140.5131	170.9931	201.4732	231.9533	262.4333	292.9134	61
62	18.89764	49.37770	79.85776	110.3378	140.8179	171.2979	201.7780	232.2581	262.7381	293.2182	62
63	19.20244	49.68250	80.16256	110.6426	141.1227	171.6027	202.0828	232.5629	263.0429	293.5230	63
64	19.50724	49.98730	80.46736	110.9474	141.4275	171.9075	202.3876	232.8677	263.3477	293.8278	64
65	19.81204	50.29210	80.77216	111.2522	141.7323	172.2123	202.6924	233.1725	263.6525	294.1326	65
66	20.11684	50.59690	81.07696	111.5570	142.0371	172.5171	202.9972	233.4773	263.9573	294.4374	66
67	20.42164	50.90170	81.38176	111.8618	142.3419	172.8219	203.3020	233.7821	264.2621	294.7422	67
68	20.72644	51.20650	81.68656	112.1666	142.6467	173.1267	203.6068	234.0869	264.5669	295.0470	68
69	21.03124	51.51130	81.99136	112.4714	142.9515	173.4315	203.9116	234.3917	264.8717	295.3518	69
70	21.33604	51.81610	82.29616	112.7762	143.2563	173.7363	204.2164	234.6965	265.1765	295.6566	70
71	21.64084	52.12090	82.60097	113.0810	143.5611	174.0411	204.5212	235.0013	265.4813	295.9614	71
72	21.94564	52.42570	82.90577	113.3858	143.8659	174.3459	204.8260	235.3061	265.7861	296.2662	72
73	22.25044	52.73050	83.21057	113.6906	144.1707	174.6507	205.1308	235.6109	266.0909	296.5710	73
74	22.55525	53.03531	83.51537	113.9954	144.4755	174.9555	205.4356	235.9157	266.3957	296.8758	74
75	22.86005	53.34011	83.82017	114.3002	144.7803	175.2604	205.7404	236.2205	266.7005	297.1806	75
76	23.16485	53.64491	84.12497	114.6050	145.0851	175.5652	206.0452	236.5253	267.0053	297.4854	76
77	23.46965	53.94971	84.42977	114.9098	145.3899	175.8700	206.3500	236.8301	267.3101	297.7902	77
78	23.77445	54.25451	84.73457	115.2146	145.6947	176.1748	206.6548	237.1349	267.6149	298.0950	78
79	24.07925	54.55931	85.03937	115.5194	145.9995	176.4796	206.9596	237.4397	267.9197	298.3998	79
80	24.38405	54.86411	85.34417	115.8242	146.3043	176.7844	207.2644	237.7445	268.2245	298.7046	80
81	24.68885	55.16891	85.64897	116.1290	146.6091	177.0892	207.5692	238.0493	268.5293	299.0094	81
82	24.99365	55.47371	85.95377	116.4338	146.9139	177.3940	207.8740	238.3541	268.8341	299.3142	82
83	25.29845	55.77851	86.25857	116.7386	147.2187	177.6988	208.1788	238.6589	269.1389	299.6190	83
84	25.60325	56.08331	86.56337	117.0434	147.5235	178.0036	208.4836	238.9637	269.4437	299.9238	84
85	25.90805	56.38811	86.86817	117.3482	147.8283	178.3084	208.7884	239.2685	269.7485	300.2286	85
86	26.21285	56.69291	87.17297	117.6530	148.1331	178.6132	209.0932	239.5733	270.0533	300.5334	86
87	26.51765	56.99771	87.47777	117.9578	148.4379	178.9180	209.3980	239.8781	270.3581	300.8382	87
88	26.82245	57.30251	87.78258	118.2626	148.7427	179.2228	209.7028	240.1829	270.6629	301.1430	88
89	27.12725	57.60732	88.08738	118.5674	149.0475	179.5276	210.0076	240.4877	270.9677	301.4478	89
90	27.43205	57.91212	88.39218	118.8722	149.3523	179.8324	210.3124	240.7925	271.2725	301.7526	90
91	27.73685	58.21692	88.69698	119.1770	149.6571	180.1372	210.6172	241.0973	271.5773	302.0574	91
92	28.04165	58.52172	89.00178	119.4818	149.9619	180.4420	210.9220	241.4021	271.8821	302.3622	92
93	28.34645	58.82652	89.30658	119.7866	150.2667	180.7468	211.2268	241.7069	272.1869	302.6670	93
94	28.65125	59.13132	89.61138	120.0914	150.5715	181.0516	211.5316	242.0117	272.4917	302.9718	94
95	28.95605	59.43612	89.91618	120.3962	150.8763	181.3564	211.8364	242.3165	272.7965	303.2766	95
96	29.26085	59.74092	90.22098	120.7010	151.1811	181.6612	212.1412	242.6213	273.1013	303.5814	96
97	29.56565	60.04572	90.52578	121.0058	151.4859	181.9660	212.4460	242.9261	273.4061	303.8862	97
98	29.87045	60.35052	90.83058	121.3106	151.7907	182.2708	212.7508	243.2309	273.7109	304.1910	98
99	30.17525	60.65532	91.13538	121.6154	152.0955	182.5756	213.0556	243.5357	274.0157	304.4958	99

When feet and inches and fractions are involved, use also Millimeter Equivalents to One Foot table, p. 314. For example, 479 ft. 7 1/2 in. = 145.9995 + .1984 = 146.1979 meters.

MILLIMETER EQUIVALENTS TO ONE FOOT

FOR EACH 32ND OF AN INCH

Inch	0"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"
0	0	25.400	50.800	76.200	101.600	127.000	152.400	177.800	203.200	228.600	254.001	279.401
1/32	.7938	26.194	51.584	76.994	102.394	127.794	153.194	178.594	203.994	229.394	254.794	280.194
1/16	1.5875	26.988	52.388	77.788	103.188	128.588	153.988	179.388	204.788	230.188	255.588	280.988
3/32	2.3813	27.781	53.181	78.581	103.981	129.382	154.782	180.182	205.582	230.982	256.382	281.782
1/8	3.1750	28.575	53.975	79.375	104.775	130.175	155.575	180.975	206.375	231.775	257.176	282.576
5/32	3.9688	29.369	54.769	80.169	105.569	130.969	156.369	181.769	207.169	232.569	257.969	283.369
3/16	4.7625	30.163	55.563	80.963	106.363	131.763	157.163	182.563	207.963	233.363	258.763	284.163
7/32	5.5563	30.956	56.356	81.756	107.156	132.557	157.957	183.357	208.757	234.157	259.557	284.957
1/4	6.3500	31.750	57.150	82.550	107.950	133.350	158.750	184.150	209.550	234.950	260.351	285.751
9/32	7.1438	32.544	57.944	83.344	108.744	134.144	159.544	184.944	210.344	235.744	261.144	286.544
5/16	7.9375	33.338	58.738	84.138	109.538	134.938	160.338	185.738	211.138	236.538	261.938	287.338
11/32	8.7313	34.131	59.531	84.931	110.331	135.732	161.132	186.532	211.932	237.332	262.732	288.132
3/8	9.5250	34.925	60.325	85.725	111.125	136.525	161.925	187.325	212.725	238.125	263.526	288.926
13/32	10.3188	35.719	61.119	86.519	111.919	137.319	162.719	188.119	213.519	238.919	264.319	289.719
7/16	11.1125	36.513	61.913	87.313	112.713	138.113	163.513	188.913	214.313	239.713	265.113	290.513
15/32	11.9063	37.306	62.706	88.106	113.506	138.907	164.307	189.707	215.107	240.507	265.907	291.307
1/2	12.7000	38.100	63.500	88.900	114.300	139.700	165.100	190.500	215.900	241.300	266.701	292.101
17/32	13.4938	38.894	64.294	89.694	115.094	140.494	165.894	191.294	216.694	242.094	267.494	292.894
9/16	14.2875	39.688	65.088	90.488	115.888	141.288	166.688	192.088	217.488	242.888	268.288	293.688
19/32	15.0813	40.481	65.881	91.281	116.681	142.082	167.482	192.882	218.282	243.682	269.082	294.482
5/8	15.8750	41.275	66.675	92.075	117.475	142.875	168.275	193.675	219.075	244.475	269.876	295.276
21/32	16.6688	42.069	67.469	92.869	118.269	143.669	169.069	194.469	219.869	245.269	270.669	296.069
11/16	17.4625	42.863	68.263	93.663	119.063	144.463	169.863	195.263	220.663	246.063	271.463	296.863
23/32	18.2563	43.656	69.056	94.456	119.856	145.257	170.657	196.057	221.457	246.857	272.257	297.657
3/4	19.0500	44.450	69.850	95.250	120.650	146.050	171.450	196.850	222.250	247.650	273.051	298.451
25/32	19.8438	45.244	70.644	96.044	121.444	146.844	172.244	197.644	223.044	248.444	273.844	299.244
13/16	20.6375	46.038	71.438	96.838	122.238	147.638	173.038	198.438	223.838	249.238	274.638	300.038
27/32	21.4313	46.831	72.231	97.631	123.032	148.432	173.832	199.232	224.632	250.032	275.432	300.832
7/8	22.2250	47.625	73.025	98.425	123.825	149.225	174.625	200.025	225.425	250.826	276.226	301.626
29/32	23.0188	48.419	73.819	99.219	124.619	150.019	175.419	200.819	226.219	251.619	277.019	302.419
15/16	23.8125	49.213	74.613	100.013	125.413	150.813	176.213	201.613	227.013	252.413	277.813	303.213
31/32	24.6063	50.006	75.406	100.806	126.207	151.607	177.007	202.407	227.807	253.207	278.607	304.007
1	25.4001											

To obtain equivalent in meters, move decimal 3 places to left. $1\frac{1}{8}" = 28.575\text{mm} = .028575\text{ m.}$

CENTIMETER—INCH INTERCONVERSION TABLE

1 INCH = 2.540005080 CM. 1 CM. = .3937 INCHES (U. S. STATUTE)

Centimeters	In. Cm.	Inches	Centimeters	In. Cm.	Inches	Centimeters	In. Cm.	Inches
.050800	.02	.007874	2.54001	1	.3937	129.54026	51	20.0787
.101600	.04	.015748	5.08001	2	.7874	132.08026	52	20.4724
.152400	.06	.023622	7.62002	3	1.1811	134.62027	53	20.8661
.203200	.08	.031496	10.16002	4	1.5748	137.16027	54	21.2598
.254001	.10	.039370	12.70003	5	1.9685	139.70028	55	21.6535
.304801	.12	.047244	15.24003	6	2.3622	142.24028	56	22.0472
.355601	.14	.055118	17.78004	7	2.7559	144.78029	57	22.4409
.406401	.16	.062992	20.32004	8	3.1496	147.32029	58	22.8346
.457201	.18	.070866	22.86005	9	3.5433	149.86030	59	23.2283
.508001	.20	.078740	25.40005	10	3.9370	152.40030	60	23.6220
.558801	.22	.086614	27.94006	11	4.3307	154.94031	61	24.0157
.609601	.24	.094488	30.48006	12	4.7244	157.48031	62	24.4094
.660401	.26	.102362	33.02007	13	5.1181	160.02032	63	24.8031
.711201	.28	.110236	35.56007	14	5.5118	162.56033	64	25.1968
.762002	.30	.118110	38.10008	15	5.9055	165.10033	65	25.5905
.812802	.32	.125984	40.64008	16	6.2992	167.64034	66	25.9842
.863602	.34	.133858	43.18009	17	6.6929	170.18034	67	26.3779
.914402	.36	.141732	45.72009	18	7.0866	172.72035	68	26.7716
.965202	.38	.149606	48.26010	19	7.4803	175.26035	69	27.1653
1.016002	.40	.157480	50.80010	20	7.8740	177.80036	70	27.5590
1.066802	.42	.165354	53.34011	21	8.2677	180.34036	71	27.9527
1.117602	.44	.173228	55.88011	22	8.6614	182.88037	72	28.3464
1.168402	.46	.181102	58.42012	23	9.0551	185.42037	73	28.7401
1.219202	.48	.188976	60.96012	24	9.4488	187.96038	74	29.1338
1.270003	.50	.196850	63.50013	25	9.8425	190.50038	75	29.5275
1.320803	.52	.204724	66.04013	26	10.2362	193.04039	76	29.9212
1.371603	.54	.212598	68.58014	27	10.6299	195.58039	77	30.3149
1.422403	.56	.220472	71.12014	28	11.0236	198.12040	78	30.7086
1.473203	.58	.228346	73.66015	29	11.4173	200.66040	79	31.1023
1.524003	.60	.236220	76.20015	30	11.8110	203.20041	80	31.4960
1.574803	.62	.244094	78.74016	31	12.2047	205.74041	81	31.8897
1.625603	.64	.251968	81.28016	32	12.5984	208.28042	82	32.2834
1.676403	.66	.259842	83.82017	33	12.9921	210.82042	83	32.6771
1.727203	.68	.267716	86.36017	34	13.3858	213.36043	84	33.0708
1.778004	.70	.275590	88.90018	35	13.7795	215.90043	85	33.4645
1.828804	.72	.283464	91.44018	36	14.1732	218.44044	86	33.8582
1.879604	.74	.291338	93.98019	37	14.5669	220.98044	87	34.2519
1.930404	.76	.299212	96.52019	38	14.9606	223.52045	88	34.6456
1.981204	.78	.307086	99.06020	39	15.3543	226.06045	89	35.0393
2.032004	.80	.314960	101.60020	40	15.7480	228.60046	90	35.4330
2.082804	.82	.322834	104.14021	41	16.1417	231.14046	91	35.8267
2.133604	.84	.330708	106.68021	42	16.5354	233.68047	92	36.2204
2.184404	.86	.338582	109.22022	43	16.9291	236.22047	93	36.6141
2.235204	.88	.346456	111.76022	44	17.3228	238.76048	94	37.0078
2.286005	.90	.354330	114.30023	45	17.7165	241.30048	95	37.4015
2.336805	.92	.362204	116.84023	46	18.1102	243.84049	96	37.7952
2.387605	.94	.370078	119.38024	47	18.5039	246.38049	97	38.1889
2.438405	.96	.377952	121.92024	48	18.8976	248.92050	98	38.5826
2.489205	.98	.385826	124.46025	49	19.2913	251.46050	99	38.9763
2.540005	1.00	.393700	127.00025	50	19.6850	254.00051	100	39.3700

Look up value to be converted in middle column. If in inches, read centimeter equivalent in left column; if in centimeters, read inch equivalent in right column.

COMPARISON OF THE VARIOUS TONS AND POUNDS IN USE IN THE UNITED STATES

Troy Pounds	Avoirdupois Pounds	Kilograms	Short Tons	Long Tons	Metric Tons
1	.822 857	.373 24	.000 411 43	.000 367 35	.000 373 24
2	1.645 71	.746 48	.000 822 86	.000 734 69	.000 746 48
3	2.468 57	1.119 73	.001 234 29	.001 102 04	.001 119 73
4	3.291 43	1.492 97	.001 645 71	.001 469 39	.001 492 97
5	4.114 29	1.866 21	.002 057 14	.001 836 73	.001 866 21
6	4.937 14	2.239 45	.002 468 57	.002 204 08	.002 239 45
7	5.760 00	2.612 69	.002 880 00	.002 571 43	.002 612 69
8	6.582 86	2.985 93	.003 291 43	.002 938 78	.002 985 93
9	7.405 71	3.359 18	.003 702 86	.003 306 12	.003 359 18
1.215 28	1	.453 59	.0005	.000 446 43	.000 453 59
2.430 56	2	.907 18	.0010	.000 892 86	.000 907 18
3.645 83	3	1.360 78	.0015	.001 339 29	.001 360 78
4.861 11	4	1.814 37	.0020	.001 785 71	.001 814 37
6.076 39	5	2.267 96	.0025	.002 232 14	.002 267 96
7.291 67	6	2.721 55	.0030	.002 678 57	.002 721 55
8.506 94	7	3.175 15	.0035	.003 125 00	.003 175 15
9.722 22	8	3.628 74	.0040	.003 571 43	.003 628 74
10.937 50	9	4.082 33	.0045	.004 017 86	.004 082 33
2.679 23	2.204 62	1	.001 102 31	.000 984 21	.001
5.358 46	4.409 24	2	.002 204 62	.001 968 41	.002
8.037 69	6.613 87	3	.003 306 93	.002 952 62	.003
10.716 91	8.818 49	4	.004 409 24	.003 936 83	.004
13.396 14	11.023 11	5	.005 511 56	.004 921 03	.005
16.075 37	13.227 73	6	.006 613 87	.005 905 24	.006
18.754 60	15.432 36	7	.007 716 18	.006 889 44	.007
21.433 83	17.636 98	8	.008 818 49	.007 873 65	.008
24.113 06	19.841 60	9	.009 920 80	.008 857 86	.009
2430.56	2000	907.18	1	.892 86	.907 18
4861.11	4000	1814.37	2	1.785 71	1.814 37
7291.67	6000	2721.55	3	2.678 57	2.721 55
9722.22	8000	3628.74	4	3.571 43	3.628 74
12 152.78	10 000	4535.92	5	4.464 29	4 535 92
14 583.33	12 000	5443.11	6	5.357 14	5.443 11
17 013.89	14 000	6350.29	7	6.250 00	6.350 29
19 444.44	16 000	7257.48	8	7.142 86	7.257 48
21 875.00	18 000	8164.66	9	8.035 71	8.164 66
2722.22	2240	1016.05	1.12	1	1.016 05
5444.44	4480	2032.09	2.24	2	2.032 09
8166.67	6720	3048.14	3.36	3	3.048 14
10 888.89	8960	4064.19	4.48	4	4.064 19
13 611.11	11 200	5080.24	5.60	5	5.080 24
16 333.33	13 440	6096.28	6.72	6	6.096 28
19 055.56	15 680	7112.33	7.84	7	7.112 33
21 777.78	17 920	8128.38	8.96	8	8.128 38
24 500.00	20 160	9144.42	10.08	9	9.144 42
2679.23	2204.62	1000	1.102 31	.984 21	1
5358.46	4409.24	2000	2.204 62	1.968 41	2
8037.69	6613.87	3000	3.306 93	2.952 62	3
10 716.91	8818.49	4000	4.409 24	3.936 83	4
13 396.14	11 023.11	5000	5.511 56	4.921 03	5
16 075.37	13 227.73	6000	6.613 87	5.905 24	6
18 754.60	15 432.36	7000	7.716 18	6.889 44	7
21 433.83	17 636.98	8000	8.818 49	7.873 65	8
24 113.06	19 841.60	9000	9.920 80	8.857 86	9

LOAD CONVERSION TABLE FOR TESTING

TONS PER SQUARE INCH TO POUNDS PER SQUARE INCH						KILOGRAMS PER SQUARE MILLIMETER TO POUNDS PER SQUARE INCH					
Tons per Sq. in.	Pounds per Sq. in.	Tons per Sq. in.	Pounds per Sq. in.	Tons per Sq. in.	Pounds per Sq. in.	Kg. per Sq. mm.	Pounds per Sq. in.	Kg. per Sq. mm.	Pounds per Sq. in.	Kg. per Sq. mm.	Pounds per Sq. in.
10.0	22,400	35.0	78,400	70	156,800	10	14,223	60	85,340	110	156,457
10.5	23,520	35.5	79,520	71	159,040	11	15,646	61	86,763	111	157,880
11.0	24,640	36.0	80,640	72	161,280	12	17,068	62	88,185	112	159,302
11.5	25,760	36.5	81,760	73	163,520	13	18,490	63	89,607	113	160,724
12.0	26,880	37.0	82,880	74	165,760	14	19,913	64	91,030	114	162,147
12.5	28,000	37.5	84,000	75	168,000	15	21,335	65	92,452	115	163,569
13.0	29,120	38.0	85,120	76	170,240	16	22,757	66	93,874	116	164,991
13.5	30,240	38.5	86,240	77	172,480	17	24,180	67	95,297	117	166,414
14.0	31,360	39.0	87,360	78	174,720	18	25,602	68	96,719	118	167,836
14.5	32,480	39.5	88,480	79	176,960	19	27,024	69	98,141	119	169,258
15.0	33,600	40.0	89,600	80	179,200	20	28,447	70	99,564	120	170,681
15.5	34,720	40.5	90,720	81	181,440	21	29,869	71	100,986	121	172,103
16.0	35,840	41.0	91,840	82	183,680	22	31,291	72	102,408	122	173,525
16.5	36,960	41.5	92,960	83	185,920	23	32,714	73	103,831	123	174,948
17.0	38,080	42.0	94,080	84	188,160	24	34,136	74	105,253	124	176,370
17.5	39,200	42.5	95,200	85	190,400	25	35,558	75	106,675	125	177,792
18.0	40,320	43.0	96,320	86	192,640	26	36,981	76	108,098	126	179,215
18.5	41,440	43.5	97,440	87	194,880	27	38,403	77	109,520	127	180,637
19.0	42,560	44.0	98,560	88	197,120	28	39,826	78	110,943	128	182,059
19.5	43,680	44.5	99,680	89	199,360	29	41,248	79	112,365	129	183,482
20.0	44,800	45.0	100,800	90	201,600	30	42,670	80	113,787	130	184,904
20.5	45,920	45.5	101,920	91	203,840	31	44,093	81	115,210	131	186,327
21.0	47,040	46.0	103,040	92	206,080	32	45,515	82	116,632	132	187,749
21.5	48,160	46.5	104,160	93	208,320	33	46,937	83	118,054	133	189,171
22.0	49,280	47.0	105,280	94	210,560	34	48,360	84	119,477	134	190,594
22.5	50,400	47.5	106,400	95	212,800	35	49,782	85	120,899	135	192,016
23.0	51,520	48.0	107,520	96	215,040	36	51,204	86	122,321	136	193,438
23.5	52,640	48.5	108,640	97	217,280	37	52,627	87	123,744	137	194,861
24.0	53,760	49.0	109,760	98	219,520	38	54,049	88	125,166	138	196,283
24.5	54,880	49.5	110,880	99	221,760	39	55,471	89	126,588	139	197,705
25.0	56,000	50	112,000	100	224,000	40	56,894	90	128,011	140	199,128
25.5	57,120	51	114,240	101	226,240	41	58,316	91	129,433	141	200,550
26.0	58,240	52	116,480	102	228,480	42	59,738	92	130,855	142	201,972
26.5	59,360	53	118,720	103	230,720	43	61,161	93	132,278	143	203,395
27.0	60,480	54	120,960	104	232,960	44	62,583	94	133,700	144	204,817
27.5	61,600	55	123,200	105	235,200	45	64,005	95	135,122	145	206,239
28.0	62,720	56	125,440	106	237,440	46	65,428	96	136,545	146	207,662
28.5	63,840	57	127,680	107	239,680	47	66,850	97	137,967	147	209,084
29.0	64,960	58	129,920	108	241,920	48	68,272	98	139,389	148	210,506
29.5	66,080	59	132,160	109	244,160	49	69,695	99	140,812	149	211,929
30.0	67,200	60	134,400	110	246,400	50	71,117	100	142,234	150	213,351
30.5	68,320	61	136,640	111	248,640	51	72,539	101	143,656	151	214,773
31.0	69,440	62	138,880	112	250,880	52	73,962	102	145,079	152	216,196
31.5	70,560	63	141,120	113	253,120	53	75,384	103	146,501	153	217,618
32.0	71,680	64	143,360	114	255,360	54	76,806	104	147,923	154	219,040
32.5	72,800	65	145,600	115	257,600	55	78,229	105	149,346	155	220,463
33.0	73,920	66	147,840	116	259,840	56	79,651	106	150,768	156	221,885
33.5	75,040	67	150,080	117	262,080	57	81,073	107	152,190	157	223,307
34.0	76,160	68	152,320	118	264,320	58	82,496	108	153,613	158	224,730
34.5	77,280	69	154,560	119	266,560	59	83,918	109	155,035	159	226,152

.01
.49

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
.01	.0001	.000001	0.1000	0.2154	2̄.00000	100000.000	.03142	.000079
.02	.0004	.000008	0.1414	0.2714	2̄.30103	50000.000	.06283	.000314
.03	.0009	.000027	0.1732	0.3107	2̄.47712	33333.333	.09425	.000707
.04	.0016	.000064	0.2000	0.3420	2̄.60206	25000.000	.12566	.001257
.05	.0025	.000125	0.2236	0.3684	2̄.69897	20000.000	.15708	.001963
.06	.0036	.000216	0.2449	0.3915	2̄.77815	16666.667	.18850	.002827
.07	.0049	.000343	0.2646	0.4121	2̄.84510	14285.714	.21991	.003848
.08	.0064	.000512	0.2828	0.4309	2̄.90309	12500.000	.25133	.005027
.09	.0081	.000729	0.3000	0.4481	2̄.95424	11111.111	.28274	.006362
.10	.0100	.001000	0.3162	0.4642	1̄.00000	10000.000	.31416	.007854
.11	.0121	.001331	0.3317	0.4791	1̄.04139	9090.909	.34558	.009503
.12	.0144	.001728	0.3464	0.4932	1̄.07918	8333.333	.37699	.011310
.13	.0169	.002197	0.3606	0.5066	1̄.11394	7692.308	.40841	.013273
.14	.0196	.002744	0.3742	0.5192	1̄.14613	7142.857	.43982	.015394
.15	.0225	.003375	0.3873	0.5313	1̄.17609	6666.667	.47124	.017671
.16	.0256	.004096	0.4000	0.5429	1̄.20412	6250.000	.50265	.020106
.17	.0289	.004913	0.4123	0.5540	1̄.23045	5882.353	.53407	.022698
.18	.0324	.005832	0.4243	0.5646	1̄.25527	5555.556	.56549	.025447
.19	.0361	.006859	0.4359	0.5749	1̄.27875	5263.158	.59690	.028353
.20	.0400	.008000	0.4472	0.5848	1̄.30103	5000.000	.62832	.031416
.21	.0441	.009261	0.4583	0.5944	1̄.32222	4761.905	.65973	.034636
.22	.0484	.010648	0.4690	0.6037	1̄.34242	4545.455	.69115	.038013
.23	.0529	.012167	0.4796	0.6127	1̄.36173	4347.826	.72257	.041548
.24	.0576	.013824	0.4899	0.6214	1̄.38021	4166.667	.75398	.045239
.25	.0625	.015625	0.5000	0.6300	1̄.39794	4000.000	.78540	.049087
.26	.0676	.017576	0.5099	0.6383	1̄.41497	3846.154	.81681	.053093
.27	.0729	.019683	0.5196	0.6463	1̄.43136	3703.704	.84823	.057256
.28	.0784	.021952	0.5292	0.6542	1̄.44716	3571.429	.87965	.061575
.29	.0841	.024389	0.5385	0.6619	1̄.46240	3448.276	.91106	.066052
.30	.0900	.027000	0.5477	0.6694	1̄.47712	3333.333	.94248	.070686
.31	.0961	.029791	0.5568	0.6768	1̄.49136	3225.807	.97389	.075477
.32	.1024	.032768	0.5657	0.6840	1̄.50515	3125.000	1.00531	.080425
.33	.1089	.035937	0.5745	0.6910	1̄.51851	3030.303	1.03673	.085530
.34	.1156	.039304	0.5831	0.6980	1̄.53148	2941.177	1.06814	.090792
.35	.1225	.042875	0.5916	0.7047	1̄.54407	2857.143	1.09956	.096211
.36	.1296	.046656	0.6000	0.7114	1̄.55630	2777.778	1.13097	.101788
.37	.1369	.050653	0.6083	0.7179	1̄.56820	2702.703	1.16239	.107521
.38	.1444	.054872	0.6164	0.7243	1̄.57978	2631.579	1.19381	.113411
.39	.1521	.059319	0.6245	0.7306	1̄.59106	2564.103	1.22522	.119459
.40	.1600	.064000	0.6325	0.7368	1̄.60206	2500.000	1.2566	.125664
.41	.1681	.068921	0.6403	0.7429	1̄.61278	2439.024	1.2881	.132025
.42	.1764	.074088	0.6481	0.7489	1̄.62325	2380.952	1.3195	.138544
.43	.1849	.079507	0.6557	0.7548	1̄.63347	2325.581	1.3509	.145220
.44	.1936	.085184	0.6633	0.7606	1̄.64345	2272.727	1.3823	.152053
.45	.2025	.091125	0.6708	0.7663	1̄.65321	2222.222	1.4137	.159043
.46	.2116	.097336	0.6782	0.7719	1̄.66276	2173.913	1.4451	.166190
.47	.2209	.103823	0.6856	0.7775	1̄.67210	2127.660	1.4765	.173494
.48	.2304	.110592	0.6928	0.7830	1̄.68124	2083.333	1.5080	.180956
.49	.2401	.117649	0.7000	0.7884	1̄.69020	2040.816	1.5394	.188574

FUNCTIONS OF NUMBERS

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.99

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
.50	.2500	.125000	0.7071	0.7937	̄.69897	2000.000	1.5708	.19635
.51	.2601	.132651	0.7141	0.7990	̄.70757	1960.784	1.6022	.20428
.52	.2704	.140608	0.7211	0.8041	̄.71600	1923.077	1.6336	.21237
.53	.2809	.148877	0.7280	0.8093	̄.72428	1886.793	1.6650	.22062
.54	.2916	.157464	0.7348	0.8143	̄.73239	1851.852	1.6965	.22902
.55	.3025	.166375	0.7416	0.8193	̄.74036	1818.182	1.7279	.23758
.56	.3136	.175616	0.7483	0.8243	̄.74819	1785.714	1.7593	.24630
.57	.3249	.185193	0.7550	0.8291	̄.75587	1754.386	1.7907	.25518
.58	.3364	.195112	0.7616	0.8340	̄.76343	1724.138	1.8221	.26421
.59	.3481	.205379	0.7681	0.8387	̄.77085	1694.915	1.8535	.27340
.60	.3600	.216000	0.7746	0.8434	̄.77815	1666.667	1.8850	.28274
.61	.3721	.226981	0.7810	0.8481	̄.78533	1639.344	1.9164	.29225
.62	.3844	.238328	0.7874	0.8527	̄.79239	1612.903	1.9478	.30191
.63	.3969	.250047	0.7937	0.8573	̄.79934	1587.302	1.9792	.31172
.64	.4096	.262144	0.8000	0.8618	̄.80618	1562.500	2.0106	.32170
.65	.4225	.274625	0.8062	0.8662	̄.81291	1538.462	2.0420	.33183
.66	.4356	.287496	0.8124	0.8707	̄.81954	1515.152	2.0735	.34212
.67	.4489	.300763	0.8185	0.8750	̄.82607	1492.537	2.1049	.35257
.68	.4624	.314432	0.8246	0.8794	̄.83251	1470.588	2.1363	.36317
.69	.4761	.328509	0.8307	0.8837	̄.83885	1449.275	2.1677	.37393
.70	.4900	.343000	0.8367	0.8879	̄.84510	1428.571	2.1991	.38485
.71	.5041	.357911	0.8426	0.8921	̄.85126	1408.451	2.2305	.39592
.72	.5184	.373248	0.8485	0.8963	̄.85733	1388.889	2.2619	.40715
.73	.5329	.389017	0.8544	0.9004	̄.86332	1369.863	2.2934	.41854
.74	.5476	.405224	0.8602	0.9045	̄.86923	1351.351	2.3248	.43008
.75	.5625	.421875	0.8660	0.9086	̄.87506	1333.333	2.3562	.44179
.76	.5776	.438976	0.8718	0.9126	̄.88081	1315.790	2.3876	.45365
.77	.5929	.456533	0.8775	0.9166	̄.88649	1298.701	2.4190	.46566
.78	.6084	.474552	0.8832	0.9205	̄.89209	1282.051	2.4504	.47784
.79	.6241	.493039	0.8888	0.9244	̄.89763	1265.823	2.4819	.49017
.80	.6400	.512000	0.8944	0.9283	̄.90309	1250.000	2.5133	.50265
.81	.6561	.531441	0.9000	0.9322	̄.90849	1234.568	2.5447	.51530
.82	.6724	.551368	0.9055	0.9360	̄.91381	1219.512	2.5761	.52810
.83	.6889	.571787	0.9110	0.9398	̄.91908	1204.819	2.6075	.54106
.84	.7056	.592704	0.9165	0.9435	̄.92428	1190.476	2.6389	.55418
.85	.7225	.614125	0.9220	0.9473	̄.92942	1176.471	2.6704	.56745
.86	.7396	.636056	0.9274	0.9510	̄.93450	1162.791	2.7018	.58088
.87	.7569	.658503	0.9327	0.9546	̄.93952	1149.425	2.7332	.59447
.88	.7744	.681472	0.9381	0.9583	̄.94448	1136.364	2.7646	.60821
.89	.7921	.704969	0.9434	0.9619	̄.94939	1123.596	2.7960	.62211
.90	.8100	.729000	0.9487	0.9655	̄.95424	1111.111	2.8274	.63617
.91	.8281	.753571	0.9539	0.9691	̄.95904	1098.901	2.8588	.65039
.92	.8464	.778688	0.9592	0.9726	̄.96379	1086.957	2.8903	.66476
.93	.8649	.804357	0.9644	0.9761	̄.96848	1075.269	2.9217	.67929
.94	.8836	.830584	0.9695	0.9796	̄.97313	1063.830	2.9531	.69398
.95	.9025	.857375	0.9747	0.9830	̄.97772	1052.632	2.9845	.70882
.96	.9216	.884736	0.9798	0.9865	̄.98227	1041.667	3.0159	.72382
.97	.9409	.912673	0.9849	0.9899	̄.98677	1030.928	3.0473	.73898
.98	.9604	.941192	0.9899	0.9933	̄.99123	1020.408	3.0788	.75430
.99	.9801	.970299	0.9950	0.9967	̄.99564	1010.101	3.1102	.76977

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FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 X Reciprocal	No. = Diameter	
							Circum.	Area
1	1	1	1.0000	1.0000	0.00000	1000.000	3.142	0.7854
2	4	8	1.4142	1.2599	0.30103	500.000	6.283	3.1416
3	9	27	1.7321	1.4422	0.47712	333.333	9.425	7.0686
4	16	64	2.0000	1.5874	0.60206	250.000	12.566	12.5664
5	25	125	2.2361	1.7100	0.69897	200.000	15.708	19.6350
6	36	216	2.4495	1.8171	0.77815	166.667	18.850	28.2743
7	49	343	2.6458	1.9129	0.84510	142.857	21.991	38.4845
8	64	512	2.8284	2.0000	0.90309	125.000	25.133	50.2655
9	81	729	3.0000	2.0801	0.95424	111.111	28.274	63.6173
10	100	1000	3.1623	2.1544	1.00000	100.000	31.416	78.5398
11	121	1331	3.3166	2.2240	1.04139	90.9091	34.558	95.0332
12	144	1728	3.4641	2.2894	1.07918	83.3333	37.699	113.097
13	169	2197	3.6056	2.3513	1.11394	76.9231	40.841	132.732
14	196	2744	3.7417	2.4101	1.14613	71.4286	43.982	153.938
15	225	3375	3.8730	2.4662	1.17609	66.6667	47.124	176.715
16	256	4096	4.0000	2.5198	1.20412	62.5000	50.265	201.062
17	289	4913	4.1231	2.5713	1.23045	58.8235	53.407	226.980
18	324	5832	4.2426	2.6207	1.25527	55.5556	56.549	254.469
19	361	6859	4.3589	2.6684	1.27875	52.6316	59.690	283.529
20	400	8000	4.4721	2.7144	1.30103	50.0000	62.832	314.159
21	441	9261	4.5826	2.7589	1.32222	47.6190	65.973	346.361
22	484	10648	4.6904	2.8020	1.34242	45.4545	69.115	380.133
23	529	12167	4.7958	2.8439	1.36173	43.4783	72.257	415.476
24	576	13824	4.8990	2.8845	1.38021	41.6667	75.398	452.389
25	625	15625	5.0000	2.9240	1.39794	40.0000	78.540	490.874
26	676	17576	5.0990	2.9625	1.41497	38.4615	81.681	530.929
27	729	19683	5.1962	3.0000	1.43136	37.0370	84.823	572.555
28	784	21952	5.2915	3.0366	1.44716	35.7143	87.965	615.752
29	841	24389	5.3852	3.0723	1.46240	34.4828	91.106	660.520
30	900	27000	5.4772	3.1072	1.47712	33.3333	94.248	706.858
31	961	29791	5.5678	3.1414	1.49136	32.2581	97.389	754.768
32	1024	32768	5.6569	3.1748	1.50515	31.2500	100.531	804.248
33	1089	35937	5.7446	3.2075	1.51851	30.3030	103.673	855.299
34	1156	39304	5.8310	3.2396	1.53148	29.4118	106.814	907.920
35	1225	42875	5.9161	3.2711	1.54407	28.5714	109.956	962.113
36	1296	46656	6.0000	3.3019	1.55630	27.7778	113.097	1017.88
37	1369	50653	6.0828	3.3322	1.56820	27.0270	116.239	1075.21
38	1444	54872	6.1644	3.3620	1.57978	26.3158	119.381	1134.11
39	1521	59319	6.2450	3.3912	1.59106	25.6410	122.522	1194.59
40	1600	64000	6.3246	3.4200	1.60206	25.0000	125.66	1256.64
41	1681	68921	6.4031	3.4482	1.61278	24.3902	128.81	1320.25
42	1764	74088	6.4807	3.4760	1.62325	23.8095	131.95	1385.44
43	1849	79507	6.5574	3.5034	1.63347	23.2558	135.09	1452.20
44	1936	85184	6.6332	3.5303	1.64345	22.7273	138.23	1520.53
45	2025	91125	6.7082	3.5569	1.65321	22.2222	141.37	1590.43
46	2116	97336	6.7823	3.5830	1.66276	21.7391	144.51	1661.90
47	2209	103823	6.8557	3.6088	1.67210	21.2766	147.65	1734.94
48	2304	110592	6.9282	3.6342	1.68124	20.8333	150.80	1809.56
49	2401	117649	7.0000	3.6593	1.69020	20.4082	153.94	1885.74

FUNCTIONS OF NUMBERS

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No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 X Reciprocal	No. = Diameter	
							Circum.	Area
50	2500	125000	7.0711	3.6840	1.69897	20.0000	157.08	1963.50
51	2601	132651	7.1414	3.7084	1.70757	19.6078	160.22	2042.82
52	2704	140608	7.2111	3.7325	1.71600	19.2308	163.36	2123.72
53	2809	148877	7.2801	3.7563	1.72428	18.8679	166.50	2206.18
54	2916	157464	7.3485	3.7798	1.73239	18.5185	169.65	2290.22
55	3025	166375	7.4162	3.8030	1.74036	18.1818	172.79	2375.83
56	3136	175616	7.4833	3.8259	1.74819	17.8571	175.93	2463.01
57	3249	185193	7.5498	3.8485	1.75587	17.5439	179.07	2551.76
58	3364	195112	7.6158	3.8709	1.76343	17.2414	182.21	2642.08
59	3481	205379	7.6811	3.8930	1.77085	16.9492	185.35	2733.97
60	3600	216000	7.7460	3.9149	1.77815	16.6667	188.50	2827.43
61	3721	226981	7.8102	3.9365	1.78533	16.3934	191.64	2922.47
62	3844	238328	7.8740	3.9579	1.79239	16.1290	194.78	3019.07
63	3969	250047	7.9373	3.9791	1.79934	15.8730	197.92	3117.25
64	4096	262144	8.0000	4.0000	1.80618	15.6250	201.06	3216.99
65	4225	274625	8.0623	4.0207	1.81291	15.3846	204.20	3318.31
66	4356	287496	8.1240	4.0412	1.81954	15.1515	207.35	3421.19
67	4489	300763	8.1854	4.0615	1.82607	14.9254	210.49	3525.65
68	4624	314432	8.2462	4.0817	1.83251	14.7059	213.63	3631.68
69	4761	328509	8.3066	4.1016	1.83885	14.4928	216.77	3739.28
70	4900	343000	8.3666	4.1213	1.84510	14.2857	219.91	3848.45
71	5041	357911	8.4261	4.1408	1.85126	14.0845	223.05	3959.19
72	5184	373248	8.4853	4.1602	1.85733	13.8889	226.19	4071.50
73	5329	389017	8.5440	4.1793	1.86332	13.6986	229.34	4185.39
74	5476	405224	8.6023	4.1983	1.86923	13.5135	232.48	4300.84
75	5625	421875	8.6603	4.2172	1.87506	13.3333	235.62	4417.86
76	5776	438976	8.7178	4.2358	1.88081	13.1579	238.76	4536.46
77	5929	456533	8.7750	4.2543	1.88649	12.9870	241.90	4656.63
78	6084	474552	8.8318	4.2727	1.89209	12.8205	245.04	4778.36
79	6241	493039	8.8882	4.2908	1.89763	12.6582	248.19	4901.67
80	6400	512000	8.9443	4.3089	1.90309	12.5000	251.33	5026.55
81	6561	531441	9.0000	4.3267	1.90849	12.3457	254.47	5153.00
82	6724	551368	9.0554	4.3445	1.91381	12.1951	257.61	5281.02
83	6889	571787	9.1104	4.3621	1.91908	12.0482	260.75	5410.61
84	7056	592704	9.1652	4.3795	1.92428	11.9048	263.89	5541.77
85	7225	614125	9.2195	4.3968	1.92942	11.7647	267.04	5674.50
86	7396	636056	9.2736	4.4140	1.93450	11.6279	270.18	5808.80
87	7569	658503	9.3274	4.4310	1.93952	11.4943	273.32	5944.68
88	7744	681472	9.3808	4.4480	1.94448	11.3636	276.46	6082.12
89	7921	704969	9.4340	4.4647	1.94939	11.2360	279.60	6221.14
90	8100	729000	9.4868	4.4814	1.95424	11.1111	282.74	6361.73
91	8281	753571	9.5394	4.4979	1.95904	10.9890	285.88	6503.88
92	8464	778688	9.5917	4.5144	1.96379	10.8696	289.03	6647.61
93	8649	804357	9.6437	4.5307	1.96848	10.7527	292.17	6792.91
94	8836	830584	9.6954	4.5468	1.97313	10.6383	295.31	6939.78
95	9025	857375	9.7468	4.5629	1.97772	10.5263	298.45	7088.22
96	9216	884736	9.7980	4.5789	1.98227	10.4167	301.59	7238.23
97	9409	912673	9.8489	4.5947	1.98677	10.3093	304.73	7389.81
98	9604	941192	9.8995	4.6104	1.99123	10.2041	307.88	7542.96
99	9801	970299	9.9499	4.6261	1.99564	10.1010	311.02	7697.69

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FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
100	10000	1000000	10.0000	4.6416	2.00000	10.0000	314.16	7853.98
101	10201	1030301	10.0499	4.6570	2.00432	9.90099	317.30	8011.85
102	10404	1061208	10.0995	4.6723	2.00860	9.80392	320.44	8171.28
103	10609	1092727	10.1489	4.6875	2.01284	9.70874	323.58	8332.29
104	10816	1124864	10.1980	4.7027	2.01703	9.61538	326.73	8494.87
105	11025	1157625	10.2470	4.7177	2.02119	9.52381	329.87	8659.01
106	11236	1191016	10.2956	4.7326	2.02531	9.43396	333.01	8824.73
107	11449	1225043	10.3441	4.7475	2.02938	9.34579	336.15	8992.02
108	11664	1259712	10.3923	4.7622	2.03342	9.25926	339.29	9160.88
109	11881	1295029	10.4403	4.7769	2.03743	9.17431	342.43	9331.32
110	12100	1331000	10.4881	4.7914	2.04139	9.09091	345.58	9503.32
111	12321	1367631	10.5357	4.8059	2.04532	9.00901	348.72	9676.89
112	12544	1404928	10.5830	4.8203	2.04922	8.92857	351.86	9852.03
113	12769	1442897	10.6301	4.8346	2.05308	8.84956	355.00	10028.7
114	12996	1481544	10.6771	4.8488	2.05690	8.77193	358.14	10207.0
115	13225	1520875	10.7238	4.8629	2.06070	8.69565	361.28	10386.9
116	13456	1560896	10.7703	4.8770	2.06446	8.62069	364.42	10568.3
117	13689	1601613	10.8167	4.8910	2.06819	8.54701	367.57	10751.3
118	13924	1643032	10.8628	4.9049	2.07188	8.47458	370.71	10935.9
119	14161	1685159	10.9087	4.9187	2.07555	8.40336	373.85	11122.0
120	14400	1728000	10.9545	4.9324	2.07918	8.33333	376.99	11309.7
121	14641	1771561	11.0000	4.9461	2.08279	8.26446	380.13	11499.0
122	14884	1815848	11.0454	4.9597	2.08636	8.19672	383.27	11689.9
123	15129	1860867	11.0905	4.9732	2.08991	8.13008	386.42	11882.3
124	15376	1906624	11.1355	4.9866	2.09342	8.06452	389.56	12076.3
125	15625	1953125	11.1803	5.0000	2.09691	8.00000	392.70	12271.8
126	15876	2000376	11.2250	5.0133	2.10037	7.93651	395.84	12469.0
127	16129	2048383	11.2694	5.0265	2.10380	7.87402	398.98	12667.7
128	16384	2097152	11.3137	5.0397	2.10721	7.81250	402.12	12868.0
129	16641	2146689	11.3578	5.0528	2.11059	7.75194	405.27	13069.8
130	16900	2197000	11.4018	5.0658	2.11394	7.69231	408.41	13273.2
131	17161	2248091	11.4455	5.0788	2.11727	7.63359	411.55	13478.2
132	17424	2299968	11.4891	5.0916	2.12057	7.57576	414.69	13684.8
133	17689	2352637	11.5326	5.1045	2.12385	7.51880	417.83	13892.9
134	17956	2406104	11.5758	5.1172	2.12710	7.46269	420.97	14102.6
135	18225	2460375	11.6190	5.1299	2.13033	7.40741	424.12	14313.9
136	18496	2515456	11.6619	5.1426	2.13354	7.35294	427.26	14526.7
137	18769	2571353	11.7047	5.1551	2.13672	7.29927	430.40	14741.1
138	19044	2628072	11.7473	5.1676	2.13988	7.24638	433.54	14957.1
139	19321	2685619	11.7898	5.1801	2.14301	7.19424	436.68	15174.7
140	19600	2744000	11.8322	5.1925	2.14613	7.14286	439.82	15393.8
141	19881	2803221	11.8743	5.2048	2.14922	7.09220	442.96	15614.5
142	20164	2863288	11.9164	5.2171	2.15229	7.04225	446.11	15836.8
143	20449	2924207	11.9583	5.2293	2.15534	6.99301	449.25	16060.6
144	20736	2985984	12.0000	5.2415	2.15836	6.94444	452.39	16286.0
145	21025	3048625	12.0416	5.2536	2.16137	6.89655	455.53	16513.0
146	21316	3112136	12.0830	5.2656	2.16435	6.84932	458.67	16741.5
147	21609	3176523	12.1244	5.2776	2.16732	6.80272	461.81	16971.7
148	21904	3241792	12.1655	5.2896	2.17026	6.75676	464.96	17203.4
149	22201	3307949	12.2066	5.3015	2.17319	6.71141	468.10	17436.6

FUNCTIONS OF NUMBERS

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No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 X Reciprocal	No. = Diameter	
							Circum.	Area
150	22500	3375000	12.2474	5.3133	2.17609	6.66667	471.24	17671.5
151	22801	3442951	12.2882	5.3251	2.17898	6.62252	474.38	17907.9
152	23104	3511808	12.3288	5.3368	2.18184	6.57895	477.52	18145.8
153	23409	3581577	12.3693	5.3485	2.18469	6.53595	480.66	18385.4
154	23716	3652264	12.4097	5.3601	2.18752	6.49351	483.81	18626.5
155	24025	3723875	12.4499	5.3717	2.19033	6.45161	486.95	18869.2
156	24336	3796416	12.4900	5.3832	2.19312	6.41026	490.09	19113.4
157	24649	3869893	12.5300	5.3947	2.19590	6.36943	493.23	19359.3
158	24964	3944312	12.5698	5.4061	2.19866	6.32911	496.37	19606.7
159	25281	4019679	12.6095	5.4175	2.20140	6.28931	499.51	19855.7
160	25600	4096000	12.6491	5.4288	2.20412	6.25000	502.65	20106.2
161	25921	4173281	12.6886	5.4401	2.20683	6.21118	505.80	20358.3
162	26244	4251528	12.7279	5.4514	2.20952	6.17284	508.94	20612.0
163	26569	4330747	12.7671	5.4626	2.21219	6.13497	512.08	20867.2
164	26896	4410944	12.8062	5.4737	2.21484	6.09756	515.22	21124.1
165	27225	4492125	12.8452	5.4848	2.21748	6.06061	518.36	21382.5
166	27556	4574296	12.8841	5.4959	2.22011	6.02410	521.50	21642.4
167	27889	4657463	12.9228	5.5069	2.22272	5.98802	524.65	21904.0
168	28224	4741632	12.9615	5.5178	2.22531	5.95238	527.79	22167.1
169	28561	4826809	13.0000	5.5288	2.22789	5.91716	530.93	22431.8
170	28900	4913000	13.0384	5.5397	2.23045	5.88235	534.07	22698.0
171	29241	5000211	13.0767	5.5505	2.23300	5.84795	537.21	22965.8
172	29584	5088448	13.1149	5.5613	2.23553	5.81395	540.35	23235.2
173	29929	5177717	13.1529	5.5721	2.23805	5.78035	543.50	23506.2
174	30276	5268024	13.1909	5.5828	2.24055	5.74713	546.64	23778.7
175	30625	5359375	13.2288	5.5934	2.24304	5.71429	549.78	24052.8
176	30976	5451776	13.2665	5.6041	2.24551	5.68182	552.92	24328.5
177	31329	5545233	13.3041	5.6147	2.24797	5.64972	556.06	24605.7
178	31684	5639752	13.3417	5.6252	2.25042	5.61798	559.20	24884.6
179	32041	5735339	13.3791	5.6357	2.25285	5.58659	562.35	25164.9
180	32400	5832000	13.4164	5.6462	2.25527	5.55556	565.49	25446.9
181	32761	5929741	13.4536	5.6567	2.25768	5.52486	568.63	25730.4
182	33124	6028568	13.4907	5.6671	2.26007	5.49451	571.77	26015.5
183	33489	6128487	13.5277	5.6774	2.26245	5.46448	574.91	26302.2
184	33856	6229504	13.5647	5.6877	2.26482	5.43478	578.05	26590.4
185	34225	6331625	13.6015	5.6980	2.26717	5.40541	581.19	26880.3
186	34596	6434856	13.6382	5.7083	2.26951	5.37634	584.34	27171.6
187	34969	6539203	13.6748	5.7185	2.27184	5.34759	587.48	27464.6
188	35344	6644672	13.7113	5.7287	2.27416	5.31915	590.62	27759.1
189	35721	6751269	13.7477	5.7388	2.27646	5.29101	593.76	28055.2
190	36100	6859000	13.7840	5.7489	2.27875	5.26316	596.90	28352.9
191	36481	6967871	13.8203	5.7590	2.28103	5.23560	600.04	28652.1
192	36864	7077888	13.8564	5.7690	2.28330	5.20833	603.19	28952.9
193	37249	7189057	13.8924	5.7790	2.28556	5.18135	606.33	29255.3
194	37636	7301384	13.9284	5.7890	2.28780	5.15464	609.47	29559.2
195	38025	7414875	13.9642	5.7989	2.29003	5.12821	612.61	29864.8
196	38416	7529536	14.0000	5.8088	2.29226	5.10204	615.75	30171.9
197	38809	7645373	14.0357	5.8186	2.29447	5.07614	618.89	30480.5
198	39204	7762392	14.0712	5.8285	2.29667	5.05051	622.04	30790.7
199	39601	7880599	14.1067	5.8383	2.29885	5.02513	625.18	31102.6

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FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 X Reciprocal	No. = Diameter	
							Circum.	Area
200	40000	8000000	14.1421	5.8480	2.30103	5.00000	628.32	31415.9
201	40401	8120601	14.1774	5.8578	2.30320	4.97512	631.46	31730.9
202	40804	8242408	14.2127	5.8675	2.30535	4.95050	634.60	32047.4
203	41209	8365427	14.2478	5.8771	2.30750	4.92611	637.74	32365.5
204	41616	8489664	14.2829	5.8868	2.30963	4.90196	640.88	32685.1
205	42025	8615125	14.3178	5.8964	2.31175	4.87805	644.03	33006.4
206	42436	8741816	14.3527	5.9059	2.31387	4.85437	647.17	33329.2
207	42849	8869743	14.3875	5.9155	2.31597	4.83092	650.31	33653.5
208	43264	8998912	14.4222	5.9250	2.31806	4.80769	653.45	33979.5
209	43681	9129329	14.4568	5.9345	2.32015	4.78469	656.59	34307.0
210	44100	9261000	14.4914	5.9439	2.32222	4.76190	659.73	34636.1
211	44521	9393931	14.5258	5.9533	2.32428	4.73934	662.88	34966.7
212	44944	9528128	14.5602	5.9627	2.32634	4.71698	666.02	35298.9
213	45369	9663597	14.5945	5.9721	2.32838	4.69484	669.16	35632.7
214	45796	9800344	14.6287	5.9814	2.33041	4.67290	672.30	35968.1
215	46225	9938375	14.6629	5.9907	2.33244	4.65116	675.44	36305.0
216	46656	10077696	14.6969	6.0000	2.33445	4.62963	678.58	36643.5
217	47089	10218313	14.7309	6.0092	2.33646	4.60829	681.73	36983.6
218	47524	10360232	14.7648	6.0185	2.33846	4.58716	684.87	37325.3
219	47961	10503459	14.7986	6.0277	2.34044	4.56621	688.01	37668.5
220	48400	10648000	14.8324	6.0368	2.34242	4.54545	691.15	38013.3
221	48841	10793861	14.8661	6.0459	2.34439	4.52489	694.29	38359.6
222	49284	10941048	14.8997	6.0550	2.34635	4.50450	697.43	38707.6
223	49729	11089567	14.9332	6.0641	2.34830	4.48430	700.58	39057.1
224	50176	11239424	14.9666	6.0732	2.35025	4.46429	703.72	39408.1
225	50625	11390625	15.0000	6.0822	2.35218	4.44444	706.86	39760.8
226	51076	11543176	15.0333	6.0912	2.35411	4.42478	710.00	40115.0
227	51529	11697083	15.0665	6.1002	2.35603	4.40529	713.14	40470.8
228	51984	11852352	15.0997	6.1091	2.35793	4.38596	716.28	40828.1
229	52441	12008989	15.1327	6.1180	2.35984	4.36681	719.42	41187.1
230	52900	12167000	15.1658	6.1269	2.36173	4.34783	722.57	41547.6
231	53361	12326391	15.1987	6.1358	2.36361	4.32900	725.71	41909.6
232	53824	12487168	15.2315	6.1446	2.36549	4.31034	728.85	42273.3
233	54289	12649337	15.2643	6.1534	2.36736	4.29185	731.99	42638.5
234	54756	12812904	15.2971	6.1622	2.36922	4.27350	735.13	43005.3
235	55225	12977875	15.3297	6.1710	2.37107	4.25532	738.27	43373.6
236	55696	13144256	15.3623	6.1797	2.37291	4.23729	741.42	43743.5
237	56169	13312053	15.3948	6.1885	2.37475	4.21941	744.56	44115.0
238	56644	13481272	15.4272	6.1972	2.37658	4.20168	747.70	44488.1
239	57121	13651919	15.4596	6.2058	2.37840	4.18410	750.84	44862.7
240	57600	13824000	15.4919	6.2145	2.38021	4.16667	753.98	45238.9
241	58081	13997521	15.5242	6.2231	2.38202	4.14938	757.12	45616.7
242	58564	14172488	15.5563	6.2317	2.38382	4.13223	760.27	45996.1
243	59049	14348907	15.5885	6.2403	2.38561	4.11523	763.41	46377.0
244	59536	14526784	15.6205	6.2488	2.38739	4.09836	766.55	46759.5
245	60025	14706125	15.6525	6.2573	2.38917	4.08163	769.69	47143.5
246	60516	14886936	15.6844	6.2658	2.39094	4.06504	772.83	47529.2
247	61009	15069223	15.7162	6.2743	2.39270	4.04858	775.97	47916.4
248	61504	15252992	15.7480	6.2828	2.39445	4.03226	779.11	48305.1
249	62001	15438249	15.7797	6.2912	2.39620	4.01606	782.26	48695.5

FUNCTIONS OF NUMBERS

250

299

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
250	62500	15625000	15.8114	6.2996	2.39794	4.00000	785.40	49087.4
251	63001	15813251	15.8430	6.3080	2.39967	3.98406	788.54	49480.9
252	63504	16003008	15.8745	6.3164	2.40140	3.96825	791.68	49875.9
253	64009	16194277	15.9060	6.3247	2.40312	3.95257	794.82	50272.6
254	64516	16387064	15.9374	6.3330	2.40483	3.93701	797.96	50670.7
255	65025	16581375	15.9687	6.3413	2.40654	3.92157	801.11	51070.5
256	65536	16777216	16.0000	6.3496	2.40824	3.90625	804.25	51471.9
257	66049	16974593	16.0312	6.3579	2.40993	3.89105	807.39	51874.8
258	66564	17173512	16.0624	6.3661	2.41162	3.87597	810.53	52279.2
259	67081	17373979	16.0935	6.3743	2.41330	3.86100	813.67	52685.3
260	67600	17576000	16.1245	6.3825	2.41497	3.84615	816.81	53092.9
261	68121	17779581	16.1555	6.3907	2.41664	3.83142	819.96	53502.1
262	68644	17984728	16.1864	6.3988	2.41830	3.81679	823.10	53912.9
263	69169	18191447	16.2173	6.4070	2.41996	3.80228	826.24	54325.2
264	69696	18399744	16.2481	6.4151	2.42160	3.78788	829.38	54739.1
265	70225	18609625	16.2788	6.4232	2.42325	3.77358	832.52	55154.6
266	70756	18821096	16.3095	6.4312	2.42488	3.75940	835.66	55571.6
267	71289	19034163	16.3401	6.4393	2.42651	3.74532	838.81	55990.2
268	71824	19248832	16.3707	6.4473	2.42813	3.73134	841.95	56410.4
269	72361	19465109	16.4012	6.4553	2.42975	3.71747	845.09	56832.2
270	72900	19683000	16.4317	6.4633	2.43136	3.70370	848.23	57255.5
271	73441	19902511	16.4621	6.4713	2.43297	3.69004	851.37	57680.4
272	73984	20123648	16.4924	6.4792	2.43457	3.67647	854.51	58106.9
273	74529	20346417	16.5227	6.4872	2.43616	3.66300	857.65	58534.9
274	75076	20570824	16.5529	6.4951	2.43775	3.64964	860.80	58964.6
275	75625	20796875	16.5831	6.5030	2.43933	3.63636	863.94	59395.7
276	76176	21024576	16.6132	6.5108	2.44091	3.62319	867.08	59828.5
277	76729	21253933	16.6433	6.5187	2.44248	3.61011	870.22	60262.8
278	77284	21484952	16.6733	6.5265	2.44404	3.59712	873.36	60698.7
279	77841	21717639	16.7033	6.5343	2.44560	3.58423	876.50	61136.2
280	78400	21952000	16.7332	6.5421	2.44716	3.57143	879.65	61575.2
281	78961	22188041	16.7631	6.5499	2.44871	3.55872	882.79	62015.8
282	79524	22425768	16.7929	6.5577	2.45025	3.54610	885.93	62458.0
283	80089	22665187	16.8226	6.5654	2.45179	3.53357	889.07	62901.8
284	80656	22906304	16.8523	6.5731	2.45332	3.52113	892.21	63347.1
285	81225	23149125	16.8819	6.5808	2.45484	3.50877	895.35	63794.0
286	81796	23393656	16.9115	6.5885	2.45637	3.49650	898.50	64242.4
287	82369	23639903	16.9411	6.5962	2.45788	3.48432	901.64	64692.5
288	82944	23887872	16.9706	6.6039	2.45939	3.47222	904.78	65144.1
289	83521	24137569	17.0000	6.6115	2.46090	3.46021	907.92	65597.2
290	84100	24389000	17.0294	6.6191	2.46240	3.44828	911.06	66052.0
291	84681	24642171	17.0587	6.6267	2.46389	3.43643	914.20	66508.3
292	85264	24897088	17.0880	6.6343	2.46538	3.42466	917.35	66966.2
293	85849	25153757	17.1172	6.6419	2.46687	3.41297	920.49	67425.6
294	86436	25412184	17.1464	6.6494	2.46835	3.40136	923.63	67886.7
295	87025	25672375	17.1756	6.6569	2.46982	3.38983	926.77	68349.3
296	87616	25934336	17.2047	6.6644	2.47129	3.37838	929.91	68813.4
297	88209	26198073	17.2337	6.6719	2.47276	3.36700	933.05	69279.2
298	88804	26463592	17.2627	6.6794	2.47422	3.35570	936.19	69746.5
299	89401	26730899	17.2916	6.6869	2.47567	3.34448	939.34	70215.4

300
349

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 X Reciprocal	No. = Diameter	
							Circum.	Area
300	90000	27000000	17.3205	6.6943	2.47712	3.33333	942.48	70685.8
301	90601	27270901	17.3494	6.7018	2.47857	3.32226	945.62	71157.9
302	91204	27543608	17.3781	6.7092	2.48001	3.31126	948.76	71631.5
303	91809	27818127	17.4069	6.7166	2.48144	3.30033	951.90	72106.6
304	92416	28094464	17.4356	6.7240	2.48287	3.28947	955.04	72583.4
305	93025	28372625	17.4642	6.7313	2.48430	3.27869	958.19	73061.7
306	93636	28652616	17.4929	6.7387	2.48572	3.26797	961.33	73541.5
307	94249	28934443	17.5214	6.7460	2.48714	3.25733	964.47	74023.0
308	94864	29218112	17.5499	6.7533	2.48855	3.24675	967.61	74506.0
309	95481	29503629	17.5784	6.7606	2.48996	3.23625	970.75	74990.6
310	96100	29791000	17.6068	6.7679	2.49136	3.22581	973.89	75476.8
311	96721	30080231	17.6352	6.7752	2.49276	3.21543	977.04	75964.5
312	97344	30371328	17.6635	6.7824	2.49415	3.20513	980.18	76453.8
313	97969	30664297	17.6918	6.7897	2.49554	3.19489	983.32	76944.7
314	98596	30959144	17.7200	6.7969	2.49693	3.18471	986.46	77437.1
315	99225	31255875	17.7482	6.8041	2.49831	3.17460	989.60	77931.1
316	99856	31554496	17.7764	6.8113	2.49969	3.16456	992.74	78426.7
317	100489	31855013	17.8045	6.8185	2.50106	3.15457	995.88	78923.9
318	101124	32157432	17.8326	6.8256	2.50243	3.14465	999.03	79422.6
319	101761	32461759	17.8606	6.8328	2.50379	3.13480	1002.2	79922.9
320	102400	32768000	17.8885	6.8399	2.50515	3.12500	1005.3	80424.8
321	103041	33076161	17.9165	6.8470	2.50651	3.11526	1008.5	80928.2
322	103684	33386248	17.9444	6.8541	2.50786	3.10559	1011.6	81433.2
323	104329	33698267	17.9722	6.8612	2.50920	3.09598	1014.7	81939.8
324	104976	34012224	18.0000	6.8683	2.51055	3.08642	1017.9	82448.0
325	105625	34328125	18.0278	6.8753	2.51188	3.07692	1021.0	82957.7
326	106276	34645976	18.0555	6.8824	2.51322	3.06749	1024.2	83469.0
327	106929	34965783	18.0831	6.8894	2.51455	3.05810	1027.3	83981.8
328	107584	35287552	18.1108	6.8964	2.51587	3.04878	1030.4	84496.3
329	108241	35611289	18.1384	6.9034	2.51720	3.03951	1033.6	85012.3
330	108900	35937000	18.1659	6.9104	2.51851	3.03030	1036.7	85529.9
331	109561	36264691	18.1934	6.9174	2.51983	3.02115	1039.9	86049.0
332	110224	36594368	18.2209	6.9244	2.52114	3.01205	1043.0	86569.7
333	110889	36926037	18.2483	6.9313	2.52244	3.00300	1046.2	87092.0
334	111556	37259704	18.2757	6.9382	2.52375	2.99401	1049.3	87615.9
335	112225	37595375	18.3030	6.9451	2.52504	2.98507	1052.4	88141.3
336	112896	37933056	18.3303	6.9521	2.52634	2.97619	1055.6	88668.3
337	113569	38272753	18.3576	6.9589	2.52763	2.96736	1058.7	89196.9
338	114244	38614472	18.3848	6.9658	2.52892	2.95858	1061.9	89727.0
339	114921	38958219	18.4120	6.9727	2.53020	2.94985	1065.0	90258.7
340	115600	39304000	18.4391	6.9795	2.53148	2.94118	1068.1	90792.0
341	116281	39651821	18.4662	6.9864	2.53275	2.93255	1071.3	91326.9
342	116964	40001688	18.4932	6.9932	2.53403	2.92398	1074.4	91863.3
343	117649	40353607	18.5203	7.0000	2.53529	2.91545	1077.6	92401.3
344	118336	40707584	18.5472	7.0068	2.53656	2.90698	1080.7	92940.9
345	119025	41063625	18.5742	7.0136	2.53782	2.89855	1083.8	93482.0
346	119716	41421736	18.6011	7.0203	2.53908	2.89017	1087.0	94024.7
347	120409	41781923	18.6279	7.0271	2.54033	2.88184	1090.1	94569.0
348	121104	42144192	18.6548	7.0338	2.54158	2.87356	1093.3	95114.9
349	121801	42508549	18.6815	7.0406	2.54283	2.86533	1096.4	95662.3

FUNCTIONS OF NUMBERS

350

399

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 X Reciprocal	No. = Diameter	
							Circum.	Area
350	122500	42875000	18.7083	7.0473	2.54407	2.85714	1099.6	96211.3
351	123201	43243551	18.7350	7.0540	2.54531	2.84900	1102.7	96761.8
352	123904	43614208	18.7617	7.0607	2.54654	2.84091	1105.8	97314.0
353	124609	43986977	18.7883	7.0674	2.54777	2.83286	1109.0	97867.7
354	125316	44361864	18.8149	7.0740	2.54900	2.82486	1112.1	98423.0
355	126025	44738875	18.8414	7.0807	2.55023	2.81690	1115.3	98979.8
356	126736	45118016	18.8680	7.0873	2.55145	2.80899	1118.4	99538.2
357	127449	45499293	18.8944	7.0940	2.55267	2.80112	1121.5	100098
358	128164	45882712	18.9209	7.1006	2.55388	2.79330	1124.7	100660
359	128881	46268279	18.9473	7.1072	2.55509	2.78552	1127.8	101223
360	129600	46656000	18.9737	7.1138	2.55630	2.77778	1131.0	101788
361	130321	47045881	19.0000	7.1204	2.55751	2.77008	1134.1	102354
362	131044	47437928	19.0263	7.1269	2.55871	2.76243	1137.3	102922
363	131769	47832147	19.0526	7.1335	2.55991	2.75482	1140.4	103491
364	132496	48228544	19.0788	7.1400	2.56110	2.74725	1143.5	104062
365	133225	48627125	19.1050	7.1466	2.56229	2.73973	1146.7	104635
366	133956	49027896	19.1311	7.1531	2.56348	2.73224	1149.8	105209
367	134689	49430863	19.1572	7.1596	2.56467	2.72480	1153.0	105784
368	135424	49836032	19.1833	7.1661	2.56585	2.71739	1156.1	106362
369	136161	50243409	19.2094	7.1726	2.56703	2.71003	1159.2	106941
370	136900	50653000	19.2354	7.1791	2.56820	2.70270	1162.4	107521
371	137641	51064811	19.2614	7.1855	2.56937	2.69542	1165.5	108103
372	138384	51478848	19.2873	7.1920	2.57054	2.68817	1168.7	108687
373	139129	51895117	19.3132	7.1984	2.57171	2.68097	1171.8	109272
374	139876	52313624	19.3391	7.2048	2.57287	2.67380	1175.0	109858
375	140625	52734375	19.3649	7.2112	2.57403	2.66667	1178.1	110447
376	141376	53157376	19.3907	7.2177	2.57519	2.65957	1181.2	111036
377	142129	53582633	19.4165	7.2240	2.57634	2.65252	1184.4	111628
378	142884	54010152	19.4422	7.2304	2.57749	2.64550	1187.5	112221
379	143641	54439939	19.4679	7.2368	2.57864	2.63852	1190.7	112815
380	144400	54872000	19.4936	7.2432	2.57978	2.63158	1193.8	113411
381	145161	55306341	19.5192	7.2495	2.58093	2.62467	1196.9	114009
382	145924	55742968	19.5448	7.2558	2.58206	2.61780	1200.1	114608
383	146689	56181887	19.5704	7.2622	2.58320	2.61097	1203.2	115209
384	147456	56623104	19.5959	7.2685	2.58433	2.60417	1206.4	115812
385	148225	57066625	19.6214	7.2748	2.58546	2.59740	1209.5	116416
386	148996	57512456	19.6469	7.2811	2.58659	2.59067	1212.7	117021
387	149769	57960603	19.6723	7.2874	2.58771	2.58398	1215.8	117628
388	150544	58411072	19.6977	7.2936	2.58883	2.57732	1218.9	118237
389	151321	58863869	19.7231	7.2999	2.58995	2.57069	1222.1	118847
390	152100	59319000	19.7484	7.3061	2.59106	2.56410	1225.2	119459
391	152881	59776471	19.7737	7.3124	2.59218	2.55754	1228.4	120072
392	153664	60236288	19.7990	7.3186	2.59329	2.55102	1231.5	120687
393	154449	60698457	19.8242	7.3248	2.59439	2.54453	1234.6	121304
394	155236	61162984	19.8494	7.3310	2.59550	2.53807	1237.8	121922
395	156025	61629875	19.8746	7.3372	2.59660	2.53165	1240.9	122542
396	156816	62099136	19.8997	7.3434	2.59770	2.52525	1244.1	123163
397	157609	62570773	19.9249	7.3496	2.59879	2.51889	1247.2	123786
398	158404	63044792	19.9499	7.3558	2.59988	2.51256	1250.4	124410
399	159201	63521199	19.9750	7.3619	2.60097	2.50627	1253.5	125036

400
449

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
400	160000	64000000	20.0000	7.3681	2.60206	2.50000	1256.6	125664
401	160801	64481201	20.0250	7.3742	2.60314	2.49377	1259.8	126293
402	161604	64964808	20.0499	7.3803	2.60423	2.48756	1262.9	126923
403	162409	65450827	20.0749	7.3864	2.60531	2.48139	1266.1	127556
404	163216	65939264	20.0998	7.3925	2.60638	2.47525	1269.2	128190
405	164025	66430125	20.1246	7.3986	2.60746	2.46914	1272.3	128825
406	164836	66923416	20.1494	7.4047	2.60853	2.46305	1275.5	129462
407	165649	67419143	20.1742	7.4108	2.60959	2.45700	1278.6	130100
408	166464	67917312	20.1990	7.4169	2.61066	2.45098	1281.8	130741
409	167281	68417929	20.2237	7.4229	2.61172	2.44499	1284.9	131382
410	168100	68921000	20.2485	7.4290	2.61278	2.43902	1288.1	132025
411	168921	69426531	20.2731	7.4350	2.61384	2.43309	1291.2	132670
412	169744	69934528	20.2978	7.4410	2.61490	2.42718	1294.3	133317
413	170569	70444997	20.3224	7.4470	2.61595	2.42131	1297.5	133965
414	171396	70957944	20.3470	7.4530	2.61700	2.41546	1300.6	134614
415	172225	71473375	20.3715	7.4590	2.61805	2.40964	1303.8	135265
416	173056	71991296	20.3961	7.4650	2.61909	2.40385	1306.9	135918
417	173889	72511713	20.4206	7.4710	2.62014	2.39808	1310.0	136572
418	174724	73034632	20.4450	7.4770	2.62118	2.39234	1313.2	137228
419	175561	73560059	20.4695	7.4829	2.62221	2.38663	1316.3	137885
420	176400	74088000	20.4939	7.4889	2.62325	2.38095	1319.5	138544
421	177241	74618461	20.5183	7.4948	2.62428	2.37530	1322.6	139205
422	178084	75151448	20.5426	7.5007	2.62531	2.36967	1325.8	139867
423	178929	75686967	20.5670	7.5067	2.62634	2.36407	1328.9	140531
424	179776	76225024	20.5913	7.5126	2.62737	2.35849	1332.0	141196
425	180625	76765625	20.6155	7.5185	2.62839	2.35294	1335.2	141863
426	181476	77308776	20.6398	7.5244	2.62941	2.34742	1338.3	142531
427	182329	77854483	20.6640	7.5302	2.63043	2.34192	1341.5	143201
428	183184	78402752	20.6882	7.5361	2.63144	2.33645	1344.6	143872
429	184041	78953589	20.7123	7.5420	2.63246	2.33100	1347.7	144545
430	184900	79507000	20.7364	7.5478	2.63347	2.32558	1350.9	145220
431	185761	80062991	20.7605	7.5537	2.63448	2.32019	1354.0	145896
432	186624	80621568	20.7846	7.5595	2.63548	2.31481	1357.2	146574
433	187489	81182737	20.8087	7.5654	2.63649	2.30947	1360.3	147254
434	188356	81746504	20.8327	7.5712	2.63749	2.30415	1363.5	147934
435	189225	82312875	20.8567	7.5770	2.63849	2.29885	1366.6	148617
436	190096	82881856	20.8806	7.5828	2.63949	2.29358	1369.7	149301
437	190969	83453453	20.9045	7.5886	2.64048	2.28833	1372.9	149987
438	191844	84027672	20.9284	7.5944	2.64147	2.28311	1376.0	150674
439	192721	84604519	20.9523	7.6001	2.64246	2.27790	1379.2	151363
440	193600	85184000	20.9762	7.6059	2.64345	2.27273	1382.3	152053
441	194481	85766121	21.0000	7.6117	2.64444	2.26757	1385.4	152745
442	195364	86350888	21.0238	7.6174	2.64542	2.26244	1388.6	153439
443	196249	86938307	21.0476	7.6232	2.64640	2.25734	1391.7	154134
444	197136	87528384	21.0713	7.6289	2.64738	2.25225	1394.9	154830
445	198025	88121125	21.0950	7.6346	2.64836	2.24719	1398.0	155528
446	198916	88716536	21.1187	7.6403	2.64933	2.24215	1401.2	156228
447	199809	89314623	21.1424	7.6460	2.65031	2.23714	1404.3	156930
448	200704	89915392	21.1660	7.6517	2.65128	2.23214	1407.4	157633
449	201601	90518849	21.1896	7.6574	2.65225	2.22717	1410.6	158337

FUNCTIONS OF NUMBERS

450

499

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 X Reciprocal	No. = Diameter	
							Circum.	Area
450	202500	91125000	21.2132	7.6631	2.65321	2.22222	1413.7	159043
451	203401	91733851	21.2368	7.6688	2.65418	2.21729	1416.9	159751
452	204304	92345408	21.2603	7.6744	2.65514	2.21239	1420.0	160460
453	205209	92959677	21.2838	7.6801	2.65610	2.20751	1423.1	161171
454	206116	93576664	21.3073	7.6857	2.65706	2.20264	1426.3	161883
455	207025	94196375	21.3307	7.6914	2.65801	2.19780	1429.4	162597
456	207936	94818816	21.3542	7.6970	2.65896	2.19298	1432.6	163313
457	208849	95443993	21.3776	7.7026	2.65992	2.18818	1435.7	164030
458	209764	96071912	21.4009	7.7082	2.66087	2.18341	1438.8	164748
459	210681	96702579	21.4243	7.7138	2.66181	2.17865	1442.0	165468
460	211600	97336000	21.4476	7.7194	2.66276	2.17391	1445.1	166190
461	212521	97972181	21.4709	7.7250	2.66370	2.16920	1448.3	166914
462	213444	98611128	21.4942	7.7306	2.66464	2.16450	1451.4	167639
463	214369	99252847	21.5174	7.7362	2.66558	2.15983	1454.6	168365
464	215296	99897344	21.5407	7.7418	2.66652	2.15517	1457.7	169093
465	216225	100544625	21.5639	7.7473	2.66745	2.15054	1460.8	169823
466	217156	101194696	21.5870	7.7529	2.66839	2.14592	1464.0	170554
467	218089	101847563	21.6102	7.7584	2.66932	2.14133	1467.1	171287
468	219024	102503232	21.6333	7.7639	2.67025	2.13675	1470.3	172021
469	219961	103161709	21.6564	7.7695	2.67117	2.13220	1473.4	172757
470	220900	103823000	21.6795	7.7750	2.67210	2.12766	1476.5	173494
471	221841	104487111	21.7025	7.7805	2.67302	2.12314	1479.7	174234
472	222784	105154048	21.7256	7.7860	2.67394	2.11864	1482.8	174974
473	223729	105823817	21.7486	7.7915	2.67486	2.11416	1486.0	175716
474	224676	106496424	21.7715	7.7970	2.67578	2.10970	1489.1	176460
475	225625	107171875	21.7945	7.8025	2.67669	2.10526	1492.3	177205
476	226576	107850176	21.8174	7.8079	2.67761	2.10084	1495.4	177952
477	227529	108531333	21.8403	7.8134	2.67852	2.09644	1498.5	178701
478	228484	109215352	21.8632	7.8188	2.67943	2.09205	1501.7	179451
479	229441	109902239	21.8861	7.8243	2.68034	2.08768	1504.8	180203
480	230400	110592000	21.9089	7.8297	2.68124	2.08333	1508.0	180956
481	231361	111284641	21.9317	7.8352	2.68215	2.07900	1511.1	181711
482	232324	111980168	21.9545	7.8406	2.68305	2.07469	1514.2	182467
483	233289	112678587	21.9773	7.8460	2.68395	2.07039	1517.4	183225
484	234256	113379904	22.0000	7.8514	2.68485	2.06612	1520.5	183984
485	235225	114084125	22.0227	7.8568	2.68574	2.06186	1523.7	184745
486	236196	114791256	22.0454	7.8622	2.68664	2.05761	1526.8	185508
487	237169	115501303	22.0681	7.8676	2.68753	2.05339	1530.0	186272
488	238144	116214272	22.0907	7.8730	2.68842	2.04918	1533.1	187038
489	239121	116930169	22.1133	7.8784	2.68931	2.04499	1536.2	187805
490	240100	117649000	22.1359	7.8837	2.69020	2.04082	1539.4	188574
491	241081	118370771	22.1585	7.8891	2.69108	2.03666	1542.5	189345
492	242064	119095488	22.1811	7.8944	2.69197	2.03252	1545.7	190117
493	243049	119823157	22.2036	7.8998	2.69285	2.02840	1548.8	190890
494	244036	120553784	22.2261	7.9051	2.69373	2.02429	1551.9	191665
495	245025	121287375	22.2486	7.9105	2.69461	2.02020	1555.1	192442
496	246016	122023936	22.2711	7.9158	2.69548	2.01613	1558.2	193221
497	247009	122763473	22.2935	7.9211	2.69636	2.01207	1561.4	194000
498	248004	123505992	22.3159	7.9264	2.69723	2.00803	1564.5	194782
499	249001	124251499	22.3383	7.9317	2.69810	2.00401	1567.7	195565

500
549

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
500	250000	125000000	22.3607	7.9370	2.69897	2.00000	1570.8	196350
501	251001	125751501	22.3830	7.9423	2.69984	1.99601	1573.9	197136
502	252004	126506008	22.4054	7.9476	2.70070	1.99203	1577.1	197923
503	253009	127263527	22.4277	7.9528	2.70157	1.98807	1580.2	198713
504	254016	128024064	22.4499	7.9581	2.70243	1.98413	1583.4	199504
505	255025	128787625	22.4722	7.9634	2.70329	1.98020	1586.5	200296
506	256036	129554216	22.4944	7.9686	2.70415	1.97628	1589.6	201090
507	257049	130323843	22.5167	7.9739	2.70501	1.97239	1592.8	201886
508	258064	131096512	22.5389	7.9791	2.70586	1.96850	1595.9	202683
509	259081	131872229	22.5610	7.9843	2.70672	1.96464	1599.1	203482
510	260100	132651000	22.5832	7.9896	2.70757	1.96078	1602.2	204282
511	261121	133432831	22.6053	7.9948	2.70842	1.95695	1605.4	205084
512	262144	134217728	22.6274	8.0000	2.70927	1.95312	1608.5	205887
513	263169	135005697	22.6495	8.0052	2.71012	1.94932	1611.6	206692
514	264196	135796744	22.6716	8.0104	2.71096	1.94553	1614.8	207499
515	265225	136590875	22.6936	8.0156	2.71181	1.94175	1617.9	208307
516	266256	137388096	22.7156	8.0208	2.71265	1.93798	1621.1	209117
517	267289	138188413	22.7376	8.0260	2.71349	1.93424	1624.2	209928
518	268324	138991832	22.7596	8.0311	2.71433	1.93050	1627.3	210741
519	269361	139798359	22.7816	8.0363	2.71517	1.92678	1630.5	211556
520	270400	140608000	22.8035	8.0415	2.71600	1.92308	1633.6	212372
521	271441	141420761	22.8254	8.0466	2.71684	1.91939	1636.8	213189
522	272484	142236648	22.8473	8.0517	2.71767	1.91571	1639.9	214008
523	273529	143055667	22.8692	8.0569	2.71850	1.91205	1643.1	214829
524	274576	143877824	22.8910	8.0620	2.71933	1.90840	1646.2	215651
525	275625	144703125	22.9129	8.0671	2.72016	1.90476	1649.3	216475
526	276676	145531576	22.9347	8.0723	2.72099	1.90114	1652.5	217301
527	277729	146363183	22.9565	8.0774	2.72181	1.89753	1655.6	218128
528	278784	147197952	22.9783	8.0825	2.72263	1.89394	1658.8	218956
529	279841	148035889	23.0000	8.0876	2.72346	1.89036	1661.9	219787
530	280900	148877000	23.0217	8.0927	2.72428	1.88679	1665.0	220618
531	281961	149721291	23.0434	8.0978	2.72509	1.88324	1668.2	221452
532	283024	150568768	23.0651	8.1028	2.72591	1.87970	1671.3	222287
533	284089	151419437	23.0868	8.1079	2.72673	1.87617	1674.5	223123
534	285156	152273304	23.1084	8.1130	2.72754	1.87266	1677.6	223961
535	286225	153130375	23.1301	8.1180	2.72835	1.86916	1680.8	224801
536	287296	153990656	23.1517	8.1231	2.72916	1.86567	1683.9	225642
537	288369	154854153	23.1733	8.1281	2.72997	1.86220	1687.0	226484
538	289444	155720872	23.1948	8.1332	2.73078	1.85874	1690.2	227329
539	290521	156590819	23.2164	8.1382	2.73159	1.85529	1693.3	228175
540	291600	157464000	23.2379	8.1433	2.73239	1.85185	1696.5	229022
541	292681	158340421	23.2594	8.1483	2.73320	1.84843	1699.6	229871
542	293764	159220088	23.2809	8.1533	2.73400	1.84502	1702.7	230722
543	294849	160103007	23.3024	8.1583	2.73480	1.84162	1705.9	231574
544	295936	160989184	23.3238	8.1633	2.73560	1.83824	1709.0	232428
545	297025	161878625	23.3452	8.1683	2.73640	1.83486	1712.2	233283
546	298116	162771336	23.3666	8.1733	2.73719	1.83150	1715.3	234140
547	299209	163667323	23.3880	8.1783	2.73799	1.82815	1718.5	234998
548	300304	164566592	23.4094	8.1833	2.73878	1.82482	1721.6	235858
549	301401	165469149	23.4307	8.1882	2.73957	1.82149	1724.7	236720

FUNCTIONS OF NUMBERS

550

599

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
550	302500	166375000	23.4521	8.1932	2.74036	1.81818	1727.9	237583
551	303601	167284151	23.4734	8.1982	2.74115	1.81488	1731.0	238448
552	304704	168196608	23.4947	8.2031	2.74194	1.81159	1734.2	239314
553	305809	169112377	23.5160	8.2081	2.74273	1.80832	1737.3	240182
554	306916	170031464	23.5372	8.2130	2.74351	1.80505	1740.4	241051
555	308025	170953875	23.5584	8.2180	2.74429	1.80180	1743.6	241922
556	309136	171879616	23.5797	8.2229	2.74507	1.79856	1746.7	242795
557	310249	172808693	23.6008	8.2278	2.74586	1.79533	1749.9	243669
558	311364	173741112	23.6220	8.2327	2.74663	1.79211	1753.0	244545
559	312481	174676879	23.6432	8.2377	2.74741	1.78891	1756.2	245422
560	313600	175616000	23.6643	8.2426	2.74819	1.78571	1759.3	246301
561	314721	176558481	23.6854	8.2475	2.74896	1.78253	1762.4	247181
562	315844	177504328	23.7065	8.2524	2.74974	1.77936	1765.6	248063
563	316969	178453547	23.7276	8.2573	2.75051	1.77620	1768.7	248947
564	318096	179406144	23.7487	8.2621	2.75128	1.77305	1771.9	249832
565	319225	180362125	23.7697	8.2670	2.75205	1.76991	1775.0	250719
566	320356	181321496	23.7908	8.2719	2.75282	1.76678	1778.1	251607
567	321489	182284263	23.8118	8.2768	2.75358	1.76367	1781.3	252497
568	322624	183250432	23.8328	8.2816	2.75435	1.76056	1784.4	253388
569	323761	184220009	23.8537	8.2865	2.75511	1.75747	1787.6	254281
570	324900	185193000	23.8747	8.2913	2.75587	1.75439	1790.7	255176
571	326041	186169411	23.8956	8.2962	2.75664	1.75131	1793.8	256072
572	327184	187149248	23.9165	8.3010	2.75740	1.74825	1797.0	256970
573	328329	188132517	23.9374	8.3059	2.75815	1.74520	1800.1	257869
574	329476	189119224	23.9583	8.3107	2.75891	1.74216	1803.3	258770
575	330625	190109375	23.9792	8.3155	2.75967	1.73913	1806.4	259672
576	331776	191102976	24.0000	8.3203	2.76042	1.73611	1809.6	260576
577	332929	192100033	24.0208	8.3251	2.76118	1.73310	1812.7	261482
578	334084	193100552	24.0416	8.3300	2.76193	1.73010	1815.8	262389
579	335241	194104539	24.0624	8.3348	2.76268	1.72712	1819.0	263298
580	336400	195112000	24.0832	8.3396	2.76343	1.72414	1822.1	264208
581	337561	196122941	24.1039	8.3443	2.76418	1.72117	1825.3	265120
582	338724	197137368	24.1247	8.3491	2.76492	1.71821	1828.4	266033
583	339889	198155287	24.1454	8.3539	2.76567	1.71527	1831.5	266948
584	341056	199176704	24.1661	8.3587	2.76641	1.71233	1834.7	267865
585	342225	200201625	24.1868	8.3634	2.76716	1.70940	1837.8	268783
586	343396	201230056	24.2074	8.3682	2.76790	1.70648	1841.0	269703
587	344569	202262003	24.2281	8.3730	2.76864	1.70358	1844.1	270624
588	345744	203297472	24.2487	8.3777	2.76938	1.70068	1847.3	271547
589	346921	204336469	24.2693	8.3825	2.77012	1.69779	1850.4	272471
590	348100	205379000	24.2899	8.3872	2.77085	1.69492	1853.5	273397
591	349281	206425071	24.3105	8.3919	2.77159	1.69205	1856.7	274325
592	350464	207474688	24.3311	8.3967	2.77232	1.68919	1859.8	275254
593	351649	208527857	24.3516	8.4014	2.77305	1.68634	1863.0	276184
594	352836	209584584	24.3721	8.4061	2.77379	1.68350	1866.1	277117
595	354025	210644875	24.3926	8.4108	2.77452	1.68067	1869.2	278051
596	355216	211708736	24.4131	8.4155	2.77525	1.67785	1872.4	278986
597	356409	212776173	24.4336	8.4202	2.77597	1.67504	1875.5	279923
598	357604	213847192	24.4540	8.4249	2.77670	1.67224	1878.7	280862
599	358801	214921799	24.4745	8.4296	2.77743	1.66945	1881.8	281802

600
649

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
600	360000	216000000	24.4949	8.4343	2.77815	1.66667	1885.0	282743
601	361201	217081801	24.5153	8.4390	2.77887	1.66389	1888.1	283687
602	362404	218167208	24.5357	8.4437	2.77960	1.66113	1891.2	284631
603	363609	219256227	24.5561	8.4484	2.78032	1.65837	1894.4	285578
604	364816	220348864	24.5764	8.4530	2.78104	1.65563	1897.5	286526
605	366025	221445125	24.5967	8.4577	2.78176	1.65289	1900.7	287475
606	367236	222545016	24.6171	8.4623	2.78247	1.65017	1903.8	288426
607	368449	223648543	24.6374	8.4670	2.78319	1.64745	1906.9	289379
608	369664	224755712	24.6577	8.4716	2.78390	1.64474	1910.1	290333
609	370881	225866529	24.6779	8.4763	2.78462	1.64204	1913.2	291289
610	372100	226981000	24.6982	8.4809	2.78533	1.63934	1916.4	292247
611	373321	228099131	24.7184	8.4856	2.78604	1.63666	1919.5	293206
612	374544	229220928	24.7386	8.4902	2.78675	1.63399	1922.7	294166
613	375769	230346397	24.7588	8.4948	2.78746	1.63132	1925.8	295128
614	376996	231475544	24.7790	8.4994	2.78817	1.62866	1928.9	296092
615	378225	232608375	24.7992	8.5040	2.78888	1.62602	1932.1	297057
616	379456	233744896	24.8193	8.5086	2.78958	1.62338	1935.2	298024
617	380689	234885113	24.8395	8.5132	2.79029	1.62075	1938.4	298992
618	381924	236029032	24.8596	8.5178	2.79099	1.61812	1941.5	299962
619	383161	237176659	24.8797	8.5224	2.79169	1.61551	1944.6	300934
620	384400	238328000	24.8998	8.5270	2.79239	1.61290	1947.8	301907
621	385641	239483061	24.9199	8.5316	2.79309	1.61031	1950.9	302882
622	386884	240641848	24.9399	8.5362	2.79379	1.60772	1954.1	303858
623	388129	241804367	24.9600	8.5408	2.79449	1.60514	1957.2	304836
624	389376	242970624	24.9800	8.5453	2.79518	1.60256	1960.4	305815
625	390625	244140625	25.0000	8.5499	2.79588	1.60000	1963.5	306796
626	391876	245314376	25.0200	8.5544	2.79657	1.59744	1966.6	307779
627	393129	246491883	25.0400	8.5590	2.79727	1.59490	1969.8	308763
628	394384	247673152	25.0599	8.5635	2.79796	1.59236	1972.9	309748
629	395641	248858189	25.0799	8.5681	2.79865	1.58983	1976.1	310736
630	396900	250047000	25.0998	8.5726	2.79934	1.58730	1979.2	311725
631	398161	251239591	25.1197	8.5772	2.80003	1.58479	1982.3	312715
632	399424	252435968	25.1396	8.5817	2.80072	1.58228	1985.5	313707
633	400689	253636137	25.1595	8.5862	2.80140	1.57978	1988.6	314700
634	401956	254840104	25.1794	8.5907	2.80209	1.57729	1991.8	315696
635	403225	256047875	25.1992	8.5952	2.80277	1.57480	1994.9	316692
636	404496	257259456	25.2190	8.5997	2.80346	1.57233	1998.1	317690
637	405769	258474853	25.2389	8.6043	2.80414	1.56986	2001.2	318690
638	407044	259694072	25.2587	8.6088	2.80482	1.56740	2004.3	319692
639	408321	260917119	25.2784	8.6132	2.80550	1.56495	2007.5	320695
640	409600	262144000	25.2982	8.6177	2.80618	1.56250	2010.6	321699
641	410881	263374721	25.3180	8.6222	2.80686	1.56006	2013.8	322705
642	412164	264609288	25.3377	8.6267	2.80754	1.55763	2016.9	323713
643	413449	265847707	25.3574	8.6312	2.80821	1.55521	2020.0	324722
644	414736	267089984	25.3772	8.6357	2.80889	1.55280	2023.2	325733
645	416025	268336125	25.3969	8.6401	2.80956	1.55039	2026.3	326745
646	417316	269586136	25.4165	8.6446	2.81023	1.54799	2029.5	327759
647	418609	270840023	25.4362	8.6490	2.81090	1.54560	2032.6	328775
648	419904	272097792	25.4558	8.6535	2.81158	1.54321	2035.8	329792
649	421201	273359449	25.4755	8.6579	2.81224	1.54083	2038.9	330810

FUNCTIONS OF NUMBERS

650
699

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
650	422500	274625000	25.4951	8.6624	2.81291	1.53846	2042.0	331831
651	423801	275894451	25.5147	8.6668	2.81358	1.53610	2045.2	332853
652	425104	277167808	25.5343	8.6713	2.81425	1.53374	2048.3	333876
653	426409	278445077	25.5539	8.6757	2.81491	1.53139	2051.5	334901
654	427716	279726264	25.5734	8.6801	2.81558	1.52905	2054.6	335927
655	429025	281011375	25.5930	8.6845	2.81624	1.52672	2057.7	336955
656	430336	282300416	25.6125	8.6890	2.81690	1.52439	2060.9	337985
657	431649	283593393	25.6320	8.6934	2.81757	1.52207	2064.0	339016
658	432964	284890312	25.6515	8.6978	2.81823	1.51976	2067.2	340049
659	434281	286191179	25.6710	8.7022	2.81889	1.51745	2070.3	341083
660	435600	287496000	25.6905	8.7066	2.81954	1.51515	2073.5	342119
661	436921	288804781	25.7099	8.7110	2.82020	1.51286	2076.6	343157
662	438244	290117528	25.7294	8.7154	2.82086	1.51057	2079.7	344196
663	439569	291434247	25.7488	8.7198	2.82151	1.50830	2082.9	345237
664	440896	292754944	25.7682	8.7241	2.82217	1.50602	2086.0	346279
665	442225	294079625	25.7876	8.7285	2.82282	1.50376	2089.2	347323
666	443556	295408296	25.8070	8.7329	2.82347	1.50150	2092.3	348368
667	444889	296740963	25.8263	8.7373	2.82413	1.49925	2095.4	349415
668	446224	298077632	25.8457	8.7416	2.82478	1.49701	2098.6	350464
669	447561	299418309	25.8650	8.7460	2.82543	1.49477	2101.7	351514
670	448900	300763000	25.8844	8.7503	2.82607	1.49254	2104.9	352565
671	450241	302111711	25.9037	8.7547	2.82672	1.49031	2108.0	353618
672	451584	303464448	25.9230	8.7590	2.82737	1.48810	2111.2	354673
673	452929	304821217	25.9422	8.7634	2.82802	1.48588	2114.3	355730
674	454276	306182024	25.9615	8.7677	2.82866	1.48368	2117.4	356788
675	455625	307546875	25.9808	8.7721	2.82930	1.48148	2120.6	357847
676	456976	308915776	26.0000	8.7764	2.82995	1.47929	2123.7	358908
677	458329	310288733	26.0192	8.7807	2.83059	1.47710	2126.9	359971
678	459684	311665752	26.0384	8.7850	2.83123	1.47493	2130.0	361035
679	461041	313046839	26.0576	8.7893	2.83187	1.47275	2133.1	362101
680	462400	314432000	26.0768	8.7937	2.83251	1.47059	2136.3	363168
681	463761	315821241	26.0960	8.7980	2.83315	1.46843	2139.4	364237
682	465124	317214568	26.1151	8.8023	2.83378	1.46628	2142.6	365308
683	466489	318611987	26.1343	8.8066	2.83442	1.46413	2145.7	366380
684	467856	320013504	26.1534	8.8109	2.83506	1.46199	2148.8	367453
685	469225	321419125	26.1725	8.8152	2.83569	1.45985	2152.0	368528
686	470596	322828856	26.1916	8.8194	2.83632	1.45773	2155.1	369605
687	471969	324242703	26.2107	8.8237	2.83696	1.45560	2158.3	370684
688	473344	325660672	26.2298	8.8280	2.83759	1.45349	2161.4	371764
689	474721	327082769	26.2488	8.8323	2.83822	1.45138	2164.6	372845
690	476100	328509000	26.2679	8.8366	2.83885	1.44928	2167.7	373928
691	477481	329939371	26.2869	8.8408	2.83948	1.44718	2170.8	375013
692	478864	331373888	26.3059	8.8451	2.84011	1.44509	2174.0	376099
693	480249	332812557	26.3249	8.8493	2.84073	1.44300	2177.1	377187
694	481636	334255384	26.3439	8.8536	2.84136	1.44092	2180.3	378276
695	483025	335702375	26.3629	8.8578	2.84198	1.43885	2183.4	379367
696	484416	337153536	26.3818	8.8621	2.84261	1.43678	2186.5	380459
697	485809	338608873	26.4008	8.8663	2.84323	1.43472	2189.7	381553
698	487204	340068392	26.4197	8.8706	2.84386	1.43266	2192.8	382649
699	488601	341532099	26.4386	8.8748	2.84448	1.43062	2196.0	383746

700
749

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
700	490000	343000000	26.4575	8.8790	2.84510	1.42857	2199.1	384845
701	491401	344472101	26.4764	8.8833	2.84572	1.42653	2202.3	385945
702	492804	345948408	26.4953	8.8875	2.84634	1.42450	2205.4	387047
703	494209	347428927	26.5141	8.8917	2.84696	1.42248	2208.5	388151
704	495616	348913664	26.5330	8.8959	2.84757	1.42045	2211.7	389256
705	497025	350402625	26.5518	8.9001	2.84819	1.41844	2214.8	390363
706	498436	351895816	26.5707	8.9043	2.84880	1.41643	2218.0	391471
707	499849	353393243	26.5895	8.9085	2.84942	1.41443	2221.1	392580
708	501264	354894912	26.6083	8.9127	2.85003	1.41243	2224.2	393692
709	502681	356400829	26.6271	8.9169	2.85065	1.41044	2227.4	394805
710	504100	357911000	26.6458	8.9211	2.85126	1.40845	2230.5	395919
711	505521	359425431	26.6646	8.9253	2.85187	1.40647	2233.7	397035
712	506944	360944128	26.6833	8.9295	2.85248	1.40449	2236.8	398153
713	508369	362467097	26.7021	8.9337	2.85309	1.40252	2240.0	399272
714	509796	363994344	26.7208	8.9378	2.85370	1.40056	2243.1	400393
715	511225	365525875	26.7395	8.9420	2.85431	1.39860	2246.2	401515
716	512656	367061696	26.7582	8.9462	2.85491	1.39665	2249.4	402639
717	514089	368601813	26.7769	8.9503	2.85552	1.39470	2252.5	403765
718	515524	370146232	26.7955	8.9545	2.85612	1.39276	2255.7	404892
719	516961	371694959	26.8142	8.9587	2.85673	1.39082	2258.8	406020
720	518400	373248000	26.8328	8.9628	2.85733	1.38889	2261.9	407150
721	519841	374805361	26.8514	8.9670	2.85794	1.38696	2265.1	408282
722	521284	376367048	26.8701	8.9711	2.85854	1.38504	2268.2	409415
723	522729	377933067	26.8887	8.9752	2.85914	1.38313	2271.4	410550
724	524176	379503424	26.9072	8.9794	2.85974	1.38122	2274.5	411687
725	525625	381078125	26.9258	8.9835	2.86034	1.37931	2277.7	412825
726	527076	382657176	26.9444	8.9876	2.86094	1.37741	2280.8	413965
727	528529	384240583	26.9629	8.9918	2.86153	1.37552	2283.9	415106
728	529984	385828352	26.9815	8.9959	2.86213	1.37363	2287.1	416248
729	531441	387420489	27.0000	9.0000	2.86273	1.37174	2290.2	417393
730	532900	389017000	27.0185	9.0041	2.86332	1.36986	2293.4	418539
731	534361	390617891	27.0370	9.0082	2.86392	1.36799	2296.5	419686
732	535824	392223168	27.0555	9.0123	2.86451	1.36612	2299.6	420835
733	537289	393832837	27.0740	9.0164	2.86510	1.36426	2302.8	421986
734	538756	395446904	27.0924	9.0205	2.86570	1.36240	2305.9	423138
735	540225	397065375	27.1109	9.0246	2.86629	1.36054	2309.1	424292
736	541696	398688256	27.1293	9.0287	2.86688	1.35870	2312.2	425447
737	543169	400315553	27.1477	9.0328	2.86747	1.35685	2315.4	426604
738	544644	401947272	27.1662	9.0369	2.86806	1.35501	2318.5	427762
739	546121	403583419	27.1846	9.0410	2.86864	1.35318	2321.6	428922
740	547600	405224000	27.2029	9.0450	2.86923	1.35135	2324.8	430084
741	549081	406869021	27.2213	9.0491	2.86982	1.34953	2327.9	431247
742	550564	408518488	27.2397	9.0532	2.87040	1.34771	2331.1	432412
743	552049	410172407	27.2580	9.0572	2.87099	1.34590	2334.2	433578
744	553536	411830784	27.2764	9.0613	2.87157	1.34409	2337.3	434746
745	555025	413493625	27.2947	9.0654	2.87216	1.34228	2340.5	435916
746	556516	415160936	27.3130	9.0694	2.87274	1.34048	2343.6	437087
747	558009	416832723	27.3313	9.0735	2.87332	1.33869	2346.8	438259
748	559504	418508992	27.3496	9.0775	2.87390	1.33690	2349.9	439433
749	561001	420189749	27.3679	9.0816	2.87448	1.33511	2353.1	440609

FUNCTIONS OF NUMBERS

750

799

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
750	562500	421875000	27.3861	9.0856	2.87506	1.33333	2356.2	441786
751	564001	423564751	27.4044	9.0896	2.87564	1.33156	2359.3	442965
752	565504	425259008	27.4226	9.0937	2.87622	1.32979	2362.5	444146
753	567009	426957777	27.4408	9.0977	2.87680	1.32802	2365.6	445328
754	568516	428661064	27.4591	9.1017	2.87737	1.32626	2368.8	446511
755	570025	430368875	27.4773	9.1057	2.87795	1.32450	2371.9	447697
756	571536	432081216	27.4955	9.1098	2.87852	1.32275	2375.0	448883
757	573049	433798093	27.5136	9.1138	2.87910	1.32100	2378.2	450072
758	574564	435519512	27.5318	9.1178	2.87967	1.31926	2381.3	451262
759	576081	437245479	27.5500	9.1218	2.88024	1.31752	2384.5	452453
760	577600	438976000	27.5681	9.1258	2.88081	1.31579	2387.6	453646
761	579121	440711081	27.5862	9.1298	2.88138	1.31406	2390.8	454841
762	580644	442450728	27.6043	9.1338	2.88196	1.31234	2393.9	456037
763	582169	444194947	27.6225	9.1378	2.88252	1.31062	2397.0	457234
764	583696	445943744	27.6405	9.1418	2.88309	1.30890	2400.2	458434
765	585225	447697125	27.6586	9.1458	2.88366	1.30719	2403.3	459635
766	586756	449455096	27.6767	9.1498	2.88423	1.30548	2406.5	460837
767	588289	451217663	27.6948	9.1537	2.88480	1.30378	2409.6	462041
768	589824	452984832	27.7128	9.1577	2.88536	1.30208	2412.7	463247
769	591361	454756609	27.7308	9.1617	2.88593	1.30039	2415.9	464454
770	592900	456533000	27.7489	9.1657	2.88649	1.29870	2419.0	465663
771	594441	458314011	27.7669	9.1696	2.88705	1.29702	2422.2	466873
772	595984	460099648	27.7849	9.1736	2.88762	1.29534	2425.3	468085
773	597529	461889917	27.8029	9.1775	2.88818	1.29366	2428.5	469298
774	599076	463684824	27.8209	9.1815	2.88874	1.29199	2431.6	470513
775	600625	465484375	27.8388	9.1855	2.88930	1.29032	2434.7	471730
776	602176	467288576	27.8568	9.1894	2.88986	1.28866	2437.9	472948
777	603729	469097433	27.8747	9.1933	2.89042	1.28700	2441.0	474168
778	605284	470910952	27.8927	9.1973	2.89098	1.28535	2444.2	475389
779	606841	472729139	27.9106	9.2012	2.89154	1.28370	2447.3	476612
780	608400	474552000	27.9285	9.2052	2.89209	1.28205	2450.4	477836
781	609961	476379541	27.9464	9.2091	2.89265	1.28041	2453.6	479062
782	611524	478211768	27.9643	9.2130	2.89321	1.27877	2456.7	480290
783	613089	480048687	27.9821	9.2170	2.89376	1.27714	2459.9	481519
784	614656	481890304	28.0000	9.2209	2.89432	1.27551	2463.0	482750
785	616225	483736625	28.0179	9.2248	2.89487	1.27389	2466.2	483982
786	617796	485587656	28.0357	9.2287	2.89542	1.27226	2469.3	485216
787	619369	487443403	28.0535	9.2326	2.89597	1.27065	2472.4	486451
788	620944	489303872	28.0713	9.2365	2.89653	1.26904	2475.6	487688
789	622521	491169069	28.0891	9.2404	2.89708	1.26743	2478.7	488927
790	624100	493039000	28.1069	9.2443	2.89763	1.26582	2481.9	490167
791	625681	494913671	28.1247	9.2482	2.89818	1.26422	2485.0	491409
792	627264	496793088	28.1425	9.2521	2.89873	1.26263	2488.1	492652
793	628849	498677257	28.1603	9.2560	2.89927	1.26103	2491.3	493897
794	630436	500566184	28.1780	9.2599	2.89982	1.25945	2494.4	495143
795	632025	502459875	28.1957	9.2638	2.90037	1.25786	2497.6	496391
796	633616	504358336	28.2135	9.2677	2.90091	1.25628	2500.7	497641
797	635209	506261573	28.2312	9.2716	2.90146	1.25471	2503.8	498892
798	636804	508169592	28.2489	9.2754	2.90200	1.25313	2507.0	500145
799	638401	510082399	28.2666	9.2793	2.90255	1.25156	2510.1	501399

800
849

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
800	640000	512000000	28.2843	9.2832	2.90309	1.25000	2513.3	502655
801	641601	513922401	28.3019	9.2870	2.90363	1.24844	2516.4	503912
802	643204	515849608	28.3196	9.2909	2.90417	1.24688	2519.6	505171
803	644809	517781627	28.3373	9.2948	2.90472	1.24533	2522.7	506432
804	646416	519718464	28.3549	9.2986	2.90526	1.24378	2525.8	507694
805	648025	521660125	28.3725	9.3025	2.90580	1.24224	2529.0	508958
806	649636	523606616	28.3901	9.3063	2.90634	1.24069	2532.1	510223
807	651249	525557943	28.4077	9.3102	2.90687	1.23916	2535.3	511490
808	652864	527514112	28.4253	9.3140	2.90741	1.23762	2538.4	512758
809	654481	529475129	28.4429	9.3179	2.90795	1.23609	2541.5	514028
810	656100	531441000	28.4605	9.3217	2.90849	1.23457	2544.7	515300
811	657721	533411731	28.4781	9.3255	2.90902	1.23305	2547.8	516573
812	659344	535387328	28.4956	9.3294	2.90956	1.23153	2551.0	517848
813	660969	537367797	28.5132	9.3332	2.91009	1.23001	2554.1	519124
814	662596	539353144	28.5307	9.3370	2.91062	1.22850	2557.3	520402
815	664225	541343375	28.5482	9.3408	2.91116	1.22699	2560.4	521681
816	665856	543338496	28.5657	9.3447	2.91169	1.22549	2563.5	522962
817	667489	545338513	28.5832	9.3485	2.91222	1.22399	2566.7	524245
818	669124	547343432	28.6007	9.3523	2.91275	1.22249	2569.8	525529
819	670761	549353259	28.6182	9.3561	2.91328	1.22100	2573.0	526814
820	672400	551368000	28.6356	9.3599	2.91381	1.21951	2576.1	528102
821	674041	553387661	28.6531	9.3637	2.91434	1.21803	2579.2	529391
822	675684	555412248	28.6705	9.3675	2.91487	1.21655	2582.4	530681
823	677329	557441767	28.6880	9.3713	2.91540	1.21507	2585.5	531973
824	678976	559476224	28.7054	9.3751	2.91593	1.21359	2588.7	533267
825	680625	561515625	28.7228	9.3789	2.91645	1.21212	2591.8	534562
826	682276	563559976	28.7402	9.3827	2.91698	1.21065	2595.0	535858
827	683929	565609283	28.7576	9.3865	2.91751	1.20919	2598.1	537157
828	685584	567663552	28.7750	9.3902	2.91803	1.20773	2601.2	538456
829	687241	569722789	28.7924	9.3940	2.91855	1.20627	2604.4	539758
830	688900	571787000	28.8097	9.3978	2.91908	1.20482	2607.5	541061
831	690561	573856191	28.8271	9.4016	2.91960	1.20337	2610.7	542365
832	692224	575930368	28.8444	9.4053	2.92012	1.20192	2613.8	543671
833	693889	578009537	28.8617	9.4091	2.92065	1.20048	2616.9	544979
834	695556	580093704	28.8791	9.4129	2.92117	1.19904	2620.1	546288
835	697225	582182875	28.8964	9.4166	2.92169	1.19760	2623.2	547599
836	698896	584277056	28.9137	9.4204	2.92221	1.19617	2626.4	548912
837	700569	586376253	28.9310	9.4241	2.92273	1.19474	2629.5	550226
838	702244	588480472	28.9482	9.4279	2.92324	1.19332	2632.7	551541
839	703921	590589719	28.9655	9.4316	2.92376	1.19190	2635.8	552858
840	705600	592704000	28.9828	9.4354	2.92428	1.19048	2638.9	554177
841	707281	594823321	29.0000	9.4391	2.92480	1.18906	2642.1	555497
842	708964	596947688	29.0172	9.4429	2.92531	1.18765	2645.2	556819
843	710649	599077107	29.0345	9.4466	2.92583	1.18624	2648.4	558142
844	712336	601211584	29.0517	9.4503	2.92634	1.18483	2651.5	559467
845	714025	603351125	29.0689	9.4541	2.92686	1.18343	2654.6	560794
846	715716	605495736	29.0861	9.4578	2.92737	1.18203	2657.8	562122
847	717409	607645423	29.1033	9.4615	2.92788	1.18064	2660.9	563452
848	719104	609800192	29.1204	9.4652	2.92840	1.17925	2664.1	564783
849	720801	611960049	29.1376	9.4690	2.92891	1.17786	2667.2	566116

FUNCTIONS OF NUMBERS

850
899

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
850	722500	614125000	29.1548	9.4727	2.92942	1.17647	2670.4	567450
851	724201	616295051	29.1719	9.4764	2.92993	1.17509	2673.5	568786
852	725904	618470208	29.1890	9.4801	2.93044	1.17371	2676.6	570124
853	727609	620650477	29.2062	9.4838	2.93095	1.17233	2679.8	571463
854	729316	622835864	29.2233	9.4875	2.93146	1.17096	2682.9	572803
855	731025	625026375	29.2404	9.4912	2.93197	1.16959	2686.1	574146
856	732736	627222016	29.2575	9.4949	2.93247	1.16822	2689.2	575490
857	734449	629422793	29.2746	9.4986	2.93298	1.16686	2692.3	576835
858	736164	631628712	29.2916	9.5023	2.93349	1.16550	2695.5	578182
859	737881	633839779	29.3087	9.5060	2.93399	1.16414	2698.6	579530
860	739600	636056000	29.3258	9.5097	2.93450	1.16279	2701.8	580880
861	741321	638277381	29.3428	9.5134	2.93500	1.16144	2704.9	582232
862	743044	640503928	29.3598	9.5171	2.93551	1.16009	2708.1	583585
863	744769	642735647	29.3769	9.5207	2.93601	1.15875	2711.2	584940
864	746496	644972544	29.3939	9.5244	2.93651	1.15741	2714.3	586297
865	748225	647214625	29.4109	9.5281	2.93702	1.15607	2717.5	587655
866	749956	649461896	29.4279	9.5317	2.93752	1.15473	2720.6	589014
867	751689	651714363	29.4449	9.5354	2.93802	1.15340	2723.8	590375
868	753424	653972032	29.4618	9.5391	2.93852	1.15207	2726.9	591738
869	755161	656234909	29.4788	9.5427	2.93902	1.15075	2730.0	593102
870	756900	658503000	29.4958	9.5464	2.93952	1.14943	2733.2	594468
871	758641	660776311	29.5127	9.5501	2.94002	1.14811	2736.3	595835
872	760384	663054848	29.5296	9.5537	2.94052	1.14679	2739.5	597204
873	762129	665338617	29.5466	9.5574	2.94101	1.14548	2742.6	598575
874	763876	667627624	29.5635	9.5610	2.94151	1.14416	2745.8	599947
875	765625	669921875	29.5804	9.5647	2.94201	1.14286	2748.9	601320
876	767376	672221376	29.5973	9.5683	2.94250	1.14155	2752.0	602696
877	769129	674526133	29.6142	9.5719	2.94300	1.14025	2755.2	604073
878	770884	676836152	29.6311	9.5756	2.94349	1.13895	2758.3	605451
879	772641	679151439	29.6479	9.5792	2.94399	1.13766	2761.5	606831
880	774400	681472000	29.6648	9.5828	2.94448	1.13636	2764.6	608212
881	776161	683797841	29.6816	9.5865	2.94498	1.13507	2767.7	609595
882	777924	686128968	29.6985	9.5901	2.94547	1.13379	2770.9	610980
883	779689	688465387	29.7153	9.5937	2.94596	1.13250	2774.0	612366
884	781456	690807104	29.7321	9.5973	2.94645	1.13122	2777.2	613754
885	783225	693154125	29.7489	9.6010	2.94694	1.12994	2780.3	615143
886	784996	695506456	29.7658	9.6046	2.94743	1.12867	2783.5	616534
887	786769	697864103	29.7825	9.6082	2.94792	1.12740	2786.6	617927
888	788544	700227072	29.7993	9.6118	2.94841	1.12613	2789.7	619321
889	790321	702595369	29.8161	9.6154	2.94890	1.12486	2792.9	620717
890	792100	704969000	29.8329	9.6190	2.94939	1.12360	2796.0	622114
891	793881	707347971	29.8496	9.6226	2.94988	1.12233	2799.2	623513
892	795664	709732288	29.8664	9.6262	2.95036	1.12108	2802.3	624913
893	797449	712121957	29.8831	9.6298	2.95085	1.11982	2805.4	626315
894	799236	714516984	29.8998	9.6334	2.95134	1.11857	2808.6	627718
895	801025	716917375	29.9166	9.6370	2.95182	1.11732	2811.7	629124
896	802816	719323136	29.9333	9.6406	2.95231	1.11607	2814.9	630530
897	804609	721734273	29.9500	9.6442	2.95279	1.11483	2818.0	631938
898	806404	724150792	29.9666	9.6477	2.95328	1.11359	2821.2	633348
899	808201	726572699	29.9833	9.6513	2.95376	1.11235	2824.3	634760

900
949

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 X Reciprocal	No. = Diameter	
							Circum.	Area
900	810000	729000000	30.0000	9.6549	2.95424	1.11111	2827.4	636173
901	811801	731432701	30.0167	9.6585	2.95472	1.10988	2830.6	637587
902	813604	733870808	30.0333	9.6620	2.95521	1.10865	2833.7	639003
903	815409	736314327	30.0500	9.6656	2.95569	1.10742	2836.9	640421
904	817216	738763264	30.0666	9.6692	2.95617	1.10619	2840.0	641840
905	819025	741217625	30.0832	9.6727	2.95665	1.10497	2843.1	643261
906	820836	743677416	30.0998	9.6763	2.95713	1.10375	2846.3	644683
907	822649	746142643	30.1164	9.6799	2.95761	1.10254	2849.4	646107
908	824464	748613312	30.1330	9.6834	2.95809	1.10132	2852.6	647533
909	826281	751089429	30.1496	9.6870	2.95856	1.10011	2855.7	648960
910	828100	753571000	30.1662	9.6905	2.95904	1.09890	2858.8	650388
911	829921	756058031	30.1828	9.6941	2.95952	1.09769	2862.0	651818
912	831744	758550528	30.1993	9.6976	2.95999	1.09649	2865.1	653250
913	833569	761048497	30.2159	9.7012	2.96047	1.09529	2868.3	654684
914	835396	763551944	30.2324	9.7047	2.96095	1.09409	2871.4	656118
915	837225	766060875	30.2490	9.7082	2.96142	1.09290	2874.6	657555
916	839056	768575296	30.2655	9.7118	2.96190	1.09170	2877.7	658993
917	840889	771095213	30.2820	9.7153	2.96237	1.09051	2880.8	660433
918	842724	773620632	30.2985	9.7188	2.96284	1.08932	2884.0	661874
919	844561	776151559	30.3150	9.7224	2.96332	1.08814	2887.1	663317
920	846400	778688000	30.3315	9.7259	2.96379	1.08696	2890.3	664761
921	848241	781229961	30.3480	9.7294	2.96426	1.08578	2893.4	666207
922	850084	783777448	30.3645	9.7329	2.96473	1.08460	2896.5	667654
923	851929	786330467	30.3809	9.7364	2.96520	1.08342	2899.7	669103
924	853776	788889024	30.3974	9.7400	2.96567	1.08225	2902.8	670554
925	855625	791453125	30.4138	9.7435	2.96614	1.08108	2906.0	672006
926	857476	794022776	30.4302	9.7470	2.96661	1.07991	2909.1	673460
927	859329	796597983	30.4467	9.7505	2.96708	1.07875	2912.3	674915
928	861184	799178752	30.4631	9.7540	2.96755	1.07759	2915.4	676372
929	863041	801765089	30.4795	9.7575	2.96802	1.07643	2918.5	677831
930	864900	804357000	30.4959	9.7610	2.96848	1.07527	2921.7	679291
931	866761	806954491	30.5123	9.7645	2.96895	1.07411	2924.8	680752
932	868624	809557568	30.5287	9.7680	2.96942	1.07296	2928.0	682216
933	870489	812166237	30.5450	9.7715	2.96988	1.07181	2931.1	683680
934	872356	814780504	30.5614	9.7750	2.97035	1.07066	2934.2	685147
935	874225	817400375	30.5778	9.7785	2.97081	1.06952	2937.4	686615
936	876096	820025856	30.5941	9.7819	2.97128	1.06838	2940.5	688084
937	877969	822656953	30.6105	9.7854	2.97174	1.06724	2943.7	689555
938	879844	825293672	30.6268	9.7889	2.97220	1.06610	2946.8	691028
939	881721	827936019	30.6431	9.7924	2.97267	1.06496	2950.0	692502
940	883600	830584000	30.6594	9.7959	2.97313	1.06383	2953.1	693978
941	885481	833237621	30.6757	9.7993	2.97359	1.06270	2956.2	695455
942	887364	835896888	30.6920	9.8028	2.97405	1.06157	2959.4	696934
943	889249	838561807	30.7083	9.8063	2.97451	1.06045	2962.5	698415
944	891136	841232384	30.7246	9.8097	2.97497	1.05932	2965.7	699897
945	893025	843908625	30.7409	9.8132	2.97543	1.05820	2968.8	701380
946	894916	846590536	30.7571	9.8167	2.97589	1.05708	2971.9	702865
947	896809	849278123	30.7734	9.8201	2.97635	1.05597	2975.1	704352
948	898704	851971392	30.7896	9.8236	2.97681	1.05485	2978.2	705840
949	900601	854670349	30.8058	9.8270	2.97727	1.05374	2981.4	707330

FUNCTIONS OF NUMBERS

950

999

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
950	902500	857375000	30.8221	9.8305	2.97772	1.05263	2984.5	708822
951	904401	860085351	30.8383	9.8339	2.97818	1.05152	2987.7	710315
952	906304	862801408	30.8545	9.8374	2.97864	1.05042	2990.8	711809
953	908209	865523177	30.8707	9.8408	2.97909	1.04932	2993.9	713306
954	910116	868250664	30.8869	9.8443	2.97955	1.04822	2997.1	714803
955	912025	870983875	30.9031	9.8477	2.98000	1.04712	3000.2	716303
956	913936	873722816	30.9192	9.8511	2.98046	1.04603	3003.4	717804
957	915849	876467493	30.9354	9.8546	2.98091	1.04493	3006.5	719306
958	917764	879217912	30.9516	9.8580	2.98137	1.04384	3009.6	720810
959	919681	881974079	30.9677	9.8614	2.98182	1.04275	3012.8	722316
960	921600	884736000	30.9839	9.8648	2.98227	1.04167	3015.9	723823
961	923521	887503681	31.0000	9.8683	2.98272	1.04058	3019.1	725332
962	925444	890277128	31.0161	9.8717	2.98318	1.03950	3022.2	726842
963	927369	893056347	31.0322	9.8751	2.98363	1.03842	3025.4	728354
964	929296	895841344	31.0483	9.8785	2.98408	1.03734	3028.5	729867
965	931225	898632125	31.0644	9.8819	2.98453	1.03627	3031.6	731382
966	933156	901428696	31.0805	9.8854	2.98498	1.03520	3034.8	732899
967	935089	904231063	31.0966	9.8888	2.98543	1.03413	3037.9	734417
968	937024	907039232	31.1127	9.8922	2.98588	1.03306	3041.1	735937
969	938961	909853209	31.1288	9.8956	2.98632	1.03199	3044.2	737458
970	940900	912673000	31.1448	9.8990	2.98677	1.03093	3047.3	738981
971	942841	915498611	31.1609	9.9024	2.98722	1.02987	3050.5	740506
972	944784	918330048	31.1769	9.9058	2.98767	1.02881	3053.6	742032
973	946729	921167317	31.1929	9.9092	2.98811	1.02775	3056.8	743559
974	948676	924010424	31.2090	9.9126	2.98856	1.02669	3059.9	745088
975	950625	926859375	31.2250	9.9160	2.98900	1.02564	3063.1	746619
976	952576	929714176	31.2410	9.9194	2.98945	1.02459	3066.2	748151
977	954529	932574833	31.2570	9.9227	2.98989	1.02354	3069.3	749685
978	956484	935441352	31.2730	9.9261	2.99034	1.02249	3072.5	751221
979	958441	938313739	31.2890	9.9295	2.99078	1.02145	3075.6	752758
980	960400	941192000	31.3050	9.9329	2.99123	1.02041	3078.8	754296
981	962361	944076141	31.3209	9.9363	2.99167	1.01937	3081.9	755837
982	964324	946966168	31.3369	9.9396	2.99211	1.01833	3085.0	757378
983	966289	949862087	31.3528	9.9430	2.99255	1.01729	3088.2	758922
984	968256	952763904	31.3688	9.9464	2.99300	1.01626	3091.3	760466
985	970225	955671625	31.3847	9.9497	2.99344	1.01523	3094.5	762013
986	972196	958585256	31.4006	9.9531	2.99388	1.01420	3097.6	763561
987	974169	961504803	31.4166	9.9565	2.99432	1.01317	3100.8	765111
988	976144	964430272	31.4325	9.9598	2.99476	1.01215	3103.9	766662
989	978121	967361669	31.4484	9.9632	2.99520	1.01112	3107.0	768214
990	980100	970299000	31.4643	9.9666	2.99564	1.01010	3110.2	769769
991	982081	973242271	31.4802	9.9699	2.99607	1.00908	3113.3	771325
992	984064	976191488	31.4960	9.9733	2.99651	1.00806	3116.5	772882
993	986049	979146657	31.5119	9.9766	2.99695	1.00705	3119.6	774441
994	988036	982107784	31.5278	9.9800	2.99739	1.00604	3122.7	776002
995	990025	985074875	31.5436	9.9833	2.99782	1.00503	3125.9	777564
996	992016	988047936	31.5595	9.9866	2.99826	1.00402	3129.0	779128
997	994009	991026973	31.5753	9.9900	2.99870	1.00301	3132.2	780693
998	996004	994011992	31.5911	9.9933	2.99913	1.00200	3135.3	782260
999	998001	997002999	31.6070	9.9967	2.99957	1.00100	3138.5	783828

SQUARES OF NUMBERS AND FRACTIONAL INTERVALS

Fraction	0	1	2	3	4	5
0	.000000	1.00000	4.00000	9.00000	16.00000	25.00000
$\frac{1}{64}$	.000244	1.03149	4.06274	9.09399	16.12524	25.15649
$\frac{2}{64}$	.000977	1.06348	4.12598	9.18848	16.25098	25.31348
$\frac{3}{64}$	.002197	1.09595	4.18970	9.28345	16.37720	25.47095
$\frac{4}{64}$	.003906	1.12891	4.25391	9.37891	16.50391	25.62891
$\frac{5}{64}$	.006104	1.16235	4.31860	9.47485	16.63110	25.78735
$\frac{6}{64}$	.008789	1.19629	4.38379	9.57129	16.75879	25.94629
$\frac{7}{64}$	.011963	1.23071	4.44946	9.66821	16.88696	26.10571
$\frac{8}{64}$	.015625	1.26563	4.51563	9.76563	17.01563	26.26563
$\frac{9}{64}$	.019775	1.30103	4.58228	9.86353	17.14478	26.42603
$\frac{10}{64}$	.024414	1.33691	4.64941	9.96191	17.27441	26.58691
$\frac{11}{64}$	.029541	1.37329	4.71704	10.06079	17.40454	26.74829
$\frac{12}{64}$	.035156	1.41016	4.78516	10.16016	17.53516	26.91016
$\frac{13}{64}$	.041260	1.44751	4.85376	10.26001	17.66626	27.07251
$\frac{14}{64}$	.047852	1.48535	4.92285	10.36035	17.79785	27.23535
$\frac{15}{64}$	.054932	1.52368	4.99243	10.46118	17.92993	27.39868
$\frac{16}{64}$	.062500	1.56250	5.06250	10.56250	18.06250	27.56250
$\frac{17}{64}$	.070557	1.60181	5.13306	10.66431	18.19556	27.72681
$\frac{18}{64}$	.079102	1.64160	5.20410	10.76660	18.32910	27.89160
$\frac{19}{64}$	.088135	1.68188	5.27563	10.86938	18.46313	28.05688
$\frac{20}{64}$	.097656	1.72266	5.34766	10.97266	18.59766	28.22266
$\frac{21}{64}$	.107666	1.76392	5.42017	11.07642	18.73267	28.38892
$\frac{22}{64}$	.118164	1.80566	5.49316	11.18066	18.86816	28.55566
$\frac{23}{64}$	.129150	1.84790	5.56665	11.28540	19.00415	28.72290
$\frac{24}{64}$	.140625	1.89063	5.64063	11.39063	19.14063	28.89063
$\frac{25}{64}$	.152588	1.93384	5.71509	11.49634	19.27759	29.05884
$\frac{26}{64}$	.165039	1.97754	5.79004	11.60254	19.41504	29.22754
$\frac{27}{64}$	.177979	2.02173	5.86548	11.70923	19.55298	29.39673
$\frac{28}{64}$	.191406	2.06641	5.94141	11.81641	19.69141	29.56641
$\frac{29}{64}$	.205322	2.11157	6.01782	11.92407	19.83032	29.73657
$\frac{30}{64}$	.219727	2.15723	6.09473	12.03223	19.96973	29.90723
$\frac{31}{64}$	.234619	2.20337	6.17212	12.14087	20.10962	30.07837
$\frac{32}{64}$	.250000	2.25000	6.25000	12.25000	20.25000	30.25000
$\frac{33}{64}$	.265869	2.29712	6.32837	12.35962	20.39087	30.42212
$\frac{34}{64}$	.282227	2.34473	6.40723	12.46973	20.53223	30.59473
$\frac{35}{64}$	.299072	2.39282	6.48657	12.58032	20.67407	30.76782
$\frac{36}{64}$	.316406	2.44141	6.56641	12.69141	20.81641	30.94141
$\frac{37}{64}$	.334229	2.49048	6.64673	12.80298	20.95923	31.11548
$\frac{38}{64}$	.352539	2.54004	6.72754	12.91504	21.10254	31.29004
$\frac{39}{64}$	.371338	2.59009	6.80884	13.02759	21.24634	31.46509
$\frac{40}{64}$	.390625	2.64063	6.89063	13.14063	21.39063	31.64063
$\frac{41}{64}$	.410400	2.69165	6.97290	13.25415	21.53540	31.81665
$\frac{42}{64}$	.430664	2.74316	7.05566	13.36816	21.68066	31.99316
$\frac{43}{64}$	.451416	2.79517	7.13892	13.48267	21.82642	32.17017
$\frac{44}{64}$	.472656	2.84766	7.22266	13.59766	21.97266	32.34766
$\frac{45}{64}$	.494385	2.90063	7.30688	13.71313	22.11938	32.52563
$\frac{46}{64}$	.516602	2.95410	7.39160	13.82910	22.26660	32.70410
$\frac{47}{64}$	.539307	3.00806	7.47681	13.94556	22.41431	32.88306

SQUARES OF NUMBERS AND FRACTIONAL INTERVALS

Fraction	6	7	8	9	10	11
0	36.00000	49.00000	64.00000	81.00000	100.00000	121.00000
$\frac{1}{64}$	36.18774	49.21899	64.25024	81.28149	100.31274	121.34399
$\frac{1}{32}$	36.37598	49.43848	64.50098	81.56348	100.62598	121.68848
$\frac{3}{64}$	36.56470	49.65845	64.75220	81.84595	100.93970	122.03345
$\frac{1}{16}$	36.75391	49.87891	65.00391	82.12891	101.25391	122.37891
$\frac{5}{64}$	36.94360	50.09985	65.25610	82.41235	101.56860	122.72485
$\frac{3}{32}$	37.13379	50.32129	65.50879	82.69629	101.88379	123.07129
$\frac{7}{64}$	37.32446	50.54321	65.76196	82.98071	102.19946	123.41821
$\frac{1}{8}$	37.51563	50.76563	66.01563	83.26563	102.51563	123.76563
$\frac{9}{64}$	37.70728	50.98853	66.26978	83.55103	102.83228	124.11353
$\frac{5}{32}$	37.89941	51.21191	66.52441	83.83691	103.14941	124.46191
$\frac{11}{64}$	38.09204	51.43579	66.77954	84.12329	103.46704	124.81079
$\frac{3}{16}$	38.28516	51.66016	67.03516	84.41016	103.78516	125.16016
$\frac{13}{64}$	38.47876	51.88501	67.29126	84.69751	104.10376	125.51001
$\frac{7}{32}$	38.67285	52.11035	67.54785	84.98535	104.42285	125.86035
$\frac{15}{64}$	38.86743	52.33618	67.80493	85.27368	104.74243	126.21118
$\frac{1}{4}$	39.06250	52.56250	68.06250	85.56250	105.06250	126.56250
$\frac{17}{64}$	39.25806	52.78931	68.32056	85.85181	105.38306	126.91431
$\frac{9}{32}$	39.45410	53.01660	68.57910	86.14160	105.70410	127.26660
$\frac{19}{64}$	39.65063	53.24438	68.83813	86.43188	106.02563	127.61938
$\frac{5}{16}$	39.84766	53.47266	69.09766	86.72266	106.34766	127.97266
$\frac{21}{64}$	40.04517	53.70142	69.35767	87.01392	106.67017	128.32642
$\frac{11}{32}$	40.24316	53.93066	69.61816	87.30566	106.99316	128.68066
$\frac{23}{64}$	40.44165	54.16040	69.87915	87.59790	107.31665	129.03540
$\frac{3}{8}$	40.64063	54.39063	70.14063	87.89063	107.64063	129.39063
$\frac{25}{64}$	40.84009	54.62134	70.40259	88.18384	107.96509	129.74634
$\frac{13}{32}$	41.04004	54.85254	70.66504	88.47754	108.29004	130.10254
$\frac{27}{64}$	41.24048	55.08423	70.92798	88.77173	108.61548	130.45923
$\frac{7}{16}$	41.44141	55.31641	71.19141	89.06641	108.94141	130.81641
$\frac{29}{64}$	41.64282	55.54907	71.45532	89.36157	109.26782	131.17407
$\frac{15}{32}$	41.84473	55.78223	71.71973	89.65723	109.59473	131.53223
$\frac{31}{64}$	42.04712	56.01587	71.98462	89.95337	109.92212	131.89087
$\frac{1}{2}$	42.25000	56.25000	72.25000	90.25000	110.25000	132.25000
$\frac{33}{64}$	42.45337	56.48462	72.51587	90.54712	110.57837	132.60962
$\frac{17}{32}$	42.65723	56.71973	72.78223	90.84473	110.90723	132.96973
$\frac{35}{64}$	42.86157	56.95532	73.04907	91.14282	111.23657	133.33032
$\frac{9}{16}$	43.06641	57.19141	73.31641	91.44141	111.56641	133.69141
$\frac{37}{64}$	43.27173	57.42798	73.58423	91.74048	111.89673	134.05298
$\frac{19}{32}$	43.47754	57.66504	73.85254	92.04004	112.22754	134.41504
$\frac{39}{64}$	43.68384	57.90259	74.12134	92.34009	112.55884	134.77759
$\frac{5}{8}$	43.89063	58.14063	74.39063	92.64063	112.89063	135.14063
$\frac{41}{64}$	44.09790	58.37915	74.66040	92.94165	113.22290	135.50415
$\frac{21}{32}$	44.30566	58.61816	74.93066	93.24316	113.55566	135.86816
$\frac{43}{64}$	44.51392	58.85767	75.20142	93.54517	113.88892	136.23267
$\frac{11}{16}$	44.72266	59.09766	75.47266	93.84766	114.22266	136.59766
$\frac{45}{64}$	44.93188	59.33813	75.74438	94.15063	114.55688	136.96313
$\frac{23}{32}$	45.14160	59.57910	76.01660	94.45410	114.89160	137.32910
$\frac{47}{64}$	45.35181	59.82056	76.28931	94.75806	115.22681	137.69556

SQUARES OF NUMBERS AND FRACTIONAL INTERVALS

Fraction	0	1	2	3	4	5
----- $\frac{3}{4}$	.562500	3.06250	7.56250	14.06250	22.56250	33.06250
$\frac{49}{64}$ -----	.586182	3.11743	7.64868	14.17993	22.71118	33.24243
----- $\frac{25}{32}$	.610352	3.17285	7.73535	14.29785	22.86035	33.42285
$\frac{57}{64}$ -----	.635010	3.22876	7.82251	14.41626	23.01001	33.60376
----- $\frac{13}{16}$	.660156	3.28516	7.91016	14.53516	23.16016	33.78516
$\frac{53}{64}$ -----	.685791	3.34204	7.99829	14.65454	23.31079	33.96704
----- $\frac{27}{32}$	.711914	3.39941	8.08691	14.77441	23.46191	34.14941
$\frac{55}{64}$ -----	.738525	3.45728	8.17603	14.89478	23.61353	34.33228
----- $\frac{7}{8}$	.765625	3.51563	8.26563	15.01563	23.76563	34.51563
$\frac{57}{64}$ -----	.793213	3.57446	8.35571	15.13696	23.91821	34.69946
----- $\frac{29}{32}$	.821289	3.63379	8.44629	15.25879	24.07129	34.88379
$\frac{59}{64}$ -----	.849854	3.69360	8.53735	15.38110	24.22485	35.06860
----- $\frac{15}{16}$	.878906	3.75391	8.62891	15.50391	24.37891	35.25391
$\frac{61}{64}$ -----	.908447	3.81470	8.72095	15.62720	24.53345	35.43970
----- $\frac{31}{32}$	.938477	3.87598	8.81348	15.75098	24.68848	35.62598
$\frac{63}{64}$ -----	.968994	3.93774	8.90649	15.87524	24.84399	35.81274

Fraction	12	13	14	15	16	17
----- 0	144.0000	169.0000	196.0000	225.0000	256.0000	289.0000
$\frac{1}{32}$ -----	144.7510	169.8135	196.8760	225.9385	257.0010	290.0635
----- $\frac{1}{16}$	145.5039	170.6289	197.7539	226.8789	258.0039	291.1289
$\frac{3}{32}$ -----	146.2588	171.4463	198.6338	227.8213	259.0088	292.1963
----- $\frac{1}{8}$	147.0156	172.2656	199.5156	228.7656	260.0156	293.2656
$\frac{5}{32}$ -----	147.7744	173.0869	200.3994	229.7119	261.0244	294.3369
----- $\frac{3}{16}$	148.5352	173.9102	201.2852	230.6602	262.0352	295.4102
$\frac{7}{32}$ -----	149.2979	174.7354	202.1725	231.6104	263.0479	296.4854
----- $\frac{1}{4}$	150.0625	175.5625	203.0625	232.5625	264.0625	297.5625
$\frac{9}{32}$ -----	150.8291	176.3916	203.9541	233.5166	265.0791	298.6416
----- $\frac{5}{16}$	151.5977	177.2227	204.8477	234.4727	266.0977	299.7227
$\frac{11}{32}$ -----	152.3682	178.0557	205.7432	235.4307	267.1182	300.8057
----- $\frac{3}{8}$	153.1406	178.8906	206.6406	236.3906	268.1406	301.8906
$\frac{13}{32}$ -----	153.9150	179.7275	207.5400	237.3525	269.1650	302.9775
----- $\frac{7}{16}$	154.6914	180.5664	208.4414	238.3164	270.1914	304.0664
$\frac{15}{32}$ -----	155.4697	181.4072	209.3447	239.2822	271.2197	305.1572
----- $\frac{1}{2}$	156.2500	182.2500	210.2500	240.2500	272.2500	306.2500
$\frac{17}{32}$ -----	157.0322	183.0947	211.1572	241.2197	273.2822	307.3447
----- $\frac{9}{16}$	157.8164	183.9414	212.0664	242.1914	274.3164	308.4414
$\frac{19}{32}$ -----	158.6025	184.7900	212.9775	243.1650	275.3525	309.5400
----- $\frac{5}{8}$	159.3906	185.6406	213.8906	244.1406	276.3906	310.6406
$\frac{21}{32}$ -----	160.1807	186.4932	214.8057	245.1182	277.4307	311.7432
----- $\frac{11}{16}$	160.9727	187.3477	215.7227	246.0977	278.4727	312.8477
$\frac{23}{32}$ -----	161.7666	188.2041	216.6416	247.0791	279.5166	313.9541
----- $\frac{3}{4}$	162.5625	189.0625	217.5625	248.0625	280.5625	315.0625
$\frac{25}{32}$ -----	163.3604	189.9229	218.4854	249.0479	281.6104	316.1729
----- $\frac{13}{16}$	164.1602	190.7852	219.4102	250.0352	282.6602	317.2852
$\frac{27}{32}$ -----	164.9619	191.6494	220.3369	251.0244	283.7119	318.3994
----- $\frac{7}{8}$	165.7656	192.5156	221.2656	252.0156	284.7656	319.5156
$\frac{29}{32}$ -----	166.5713	193.3838	222.1963	253.0088	285.8213	320.6338
----- $\frac{15}{16}$	167.3789	194.2539	223.1289	254.0039	286.8789	321.7539
$\frac{31}{32}$ -----	168.1885	195.1260	224.0635	255.0010	287.9385	322.8760

SQUARES OF NUMBERS AND FRACTIONAL INTERVALS

Fraction	6	7	8	9	10	11
----- $\frac{3}{4}$	45.56250	60.06250	76.56250	95.06250	115.56250	138.06250
$\frac{49}{64}$ ----- $\frac{25}{32}$	45.77368	60.30493	76.83618	95.36743	115.89868	138.42993
----- $\frac{51}{64}$	45.98535	60.54785	77.11035	95.67285	116.23535	138.79785
----- $\frac{13}{16}$	46.19751	60.79126	77.38501	95.97876	116.57251	139.16626
----- $\frac{53}{64}$	46.41016	61.03516	77.66016	96.28516	116.91016	139.53516
----- $\frac{27}{32}$	46.62329	61.27954	77.93579	96.59204	117.24829	139.90454
----- $\frac{55}{64}$	46.83691	61.52441	78.21191	96.89941	117.58691	140.27441
----- $\frac{7}{8}$	47.05103	61.76978	78.48853	97.20728	117.92603	140.64478
----- $\frac{57}{64}$	47.26563	62.01563	78.76563	97.51563	118.26563	141.01563
----- $\frac{29}{32}$	47.48071	62.26196	79.04321	97.82446	118.60571	141.38696
----- $\frac{59}{64}$	47.69629	62.50879	79.32129	98.13379	118.94629	141.75879
----- $\frac{15}{16}$	47.91235	62.75610	79.59985	98.44360	119.28735	142.13110
----- $\frac{61}{64}$	48.12891	63.00391	79.87891	98.75391	119.62891	142.50391
----- $\frac{31}{32}$	48.34595	63.25220	80.15845	99.06470	119.97095	142.87720
----- $\frac{63}{64}$	48.56348	63.50098	80.43848	99.37598	120.31348	143.25098
-----	48.78149	63.75024	80.71899	99.68774	120.65649	143.62524
Fraction	18	19	20	21	22	23
----- 0	324.0000	361.0000	400.0000	441.0000	484.0000	529.0000
$\frac{1}{32}$ ----- $\frac{1}{16}$	325.1260	362.1885	401.2510	442.3135	485.3760	530.4385
----- $\frac{3}{32}$	326.2539	363.3789	402.5039	443.6289	486.7539	531.8789
----- $\frac{1}{8}$	327.3838	364.5713	403.7588	444.9463	488.1338	533.3213
----- $\frac{5}{32}$	328.5156	365.7656	405.0156	446.2656	489.5156	534.7656
----- $\frac{3}{16}$	329.6494	366.9619	406.2744	447.5869	490.8994	536.2119
----- $\frac{7}{32}$	330.7852	368.1602	407.5352	448.9102	492.2852	537.6602
----- $\frac{1}{4}$	331.9229	369.3604	408.7979	450.2354	493.6729	539.1104
----- $\frac{9}{32}$	333.0625	370.5625	410.0625	451.5625	495.0625	540.5625
----- $\frac{5}{16}$	334.2041	371.7666	411.3291	452.8916	496.4541	542.0166
----- $\frac{11}{32}$	335.3477	372.9727	412.5977	454.2227	497.8477	543.4727
----- $\frac{3}{8}$	336.4932	374.1807	413.8682	455.5557	499.2432	544.9307
----- $\frac{13}{32}$	337.6406	375.3906	415.1406	456.8906	500.6406	546.3906
----- $\frac{7}{16}$	338.7900	376.6025	416.4150	458.2275	502.0400	547.8525
----- $\frac{15}{32}$	339.9414	377.8164	417.6914	459.5664	503.4414	549.3164
----- $\frac{1}{2}$	341.0947	379.0322	418.9697	460.9072	504.8447	550.7822
----- $\frac{17}{32}$	342.2500	380.2500	420.2500	462.2500	506.2500	552.2500
----- $\frac{9}{16}$	343.4072	381.4697	421.5322	463.5947	507.6572	553.7197
----- $\frac{19}{32}$	344.5664	382.6914	422.8164	464.9414	509.0664	555.1914
----- $\frac{5}{8}$	345.7275	383.9150	424.1025	466.2900	510.4775	556.6650
----- $\frac{21}{32}$	346.8906	385.1406	425.3906	467.6406	511.8906	558.1406
----- $\frac{11}{16}$	348.0557	386.3682	426.6807	468.9932	513.3057	559.6182
----- $\frac{23}{32}$	349.2227	387.5977	427.9727	470.3477	514.7227	561.0977
----- $\frac{3}{4}$	350.3916	388.8291	429.2666	471.7041	516.1416	562.5791
----- $\frac{25}{32}$	351.5625	390.0625	430.5625	473.0625	517.5625	564.0625
----- $\frac{13}{16}$	352.7354	391.2979	431.8604	474.4229	518.9854	565.5479
----- $\frac{27}{32}$	353.9102	392.5352	433.1602	475.7852	520.4102	567.0352
----- $\frac{7}{8}$	355.0869	393.7744	434.4619	477.1494	521.8369	568.5244
----- $\frac{29}{32}$	356.2656	395.0156	435.7656	478.5156	523.2656	570.0156
----- $\frac{15}{16}$	357.4463	396.2588	437.0713	479.8838	524.6963	571.5088
----- $\frac{31}{32}$	358.6289	397.5039	438.3789	481.2539	526.1289	573.0039
-----	359.8135	398.7510	439.6885	482.6260	527.5635	574.5010

SQUARES OF NUMBERS AND FRACTIONAL INTERVALS

No.	0	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
24	576	582.0156	588.0625	594.1406	600.25	606.3906	612.5625	618.7656
25	625	631.2656	637.5625	643.8906	650.25	656.6406	663.0625	669.5156
26	676	682.5156	689.0625	695.6406	702.25	708.8906	715.5625	722.2656
27	729	735.7656	742.5625	749.3906	756.25	763.1406	770.0625	777.0156
28	784	791.0156	798.0625	805.1406	812.25	819.3906	826.5625	833.7656
29	841	848.2656	855.5625	862.8906	870.25	877.6406	885.0625	892.5156
30	900	907.5156	915.0625	922.6406	930.25	937.8906	945.5625	953.2656
31	961	968.7656	976.5625	984.3906	992.25	1000.1406	1008.0625	1016.0156
32	1024	1032.0156	1040.0625	1048.1406	1056.25	1064.3906	1072.5625	1080.7656
33	1089	1097.2656	1105.5625	1113.8906	1122.25	1130.6406	1139.0625	1147.5156
34	1156	1164.5156	1173.0625	1181.6406	1190.25	1198.8906	1207.5625	1216.2656
35	1225	1233.7656	1242.5625	1251.3906	1260.25	1269.1406	1278.0625	1287.0156
36	1296	1305.0156	1314.0625	1323.1406	1332.25	1341.3906	1350.5625	1359.7656
37	1369	1378.2656	1387.5625	1396.8906	1406.25	1415.6406	1425.0625	1434.5156
38	1444	1453.5156	1463.0625	1472.6406	1482.25	1491.8906	1501.5625	1511.2656
39	1521	1530.7656	1540.5625	1550.3906	1560.25	1570.1406	1580.0625	1590.0156
40	1600	1610.0156	1620.0625	1630.1406	1640.25	1650.3906	1660.5625	1670.7656
41	1681	1691.2656	1701.5625	1711.8906	1722.25	1732.6406	1743.0625	1753.5156
42	1764	1774.5156	1785.0625	1795.6406	1806.25	1816.8906	1827.5625	1838.2656
43	1849	1859.7656	1870.5625	1881.3906	1892.25	1903.1406	1914.0625	1925.0156
44	1936	1947.0156	1958.0625	1969.1406	1980.25	1991.3906	2002.5625	2013.7656
45	2025	2036.2656	2047.5625	2058.8906	2070.25	2081.6406	2093.0625	2104.5156
46	2116	2127.5156	2139.0625	2150.6406	2162.25	2173.8906	2185.5625	2197.2656
47	2209	2220.7656	2232.5625	2244.3906	2256.25	2268.1406	2280.0625	2292.0156
48	2304	2316.0156	2328.0625	2340.1406	2352.25	2364.3906	2376.5625	2388.7656
49	2401	2413.2656	2425.5625	2437.8906	2450.25	2462.6406	2475.0625	2487.5156
50	2500	2512.5156	2525.0625	2537.6406	2550.25	2562.8906	2575.5625	2588.2656
51	2601	2613.7656	2626.5625	2639.3906	2652.25	2665.1406	2678.0625	2691.0156
52	2704	2717.0156	2730.0625	2743.1406	2756.25	2769.3906	2782.5625	2795.7656
53	2809	2822.2656	2835.5625	2848.8906	2862.25	2875.6406	2889.0625	2902.5156
54	2916	2929.5156	2943.0625	2956.6406	2970.25	2983.8906	2997.5625	3011.2656
55	3025	3038.7656	3052.5625	3066.3906	3080.25	3094.1406	3108.0625	3122.0156
56	3136	3150.0156	3164.0625	3178.1406	3192.25	3206.3906	3220.5625	3234.7656
57	3249	3263.2656	3277.5625	3291.8906	3306.25	3320.6406	3335.0625	3349.5156
58	3364	3378.5156	3393.0625	3407.6406	3422.25	3436.8906	3451.5625	3466.2656
59	3481	3495.7656	3510.5625	3525.3906	3540.25	3555.1406	3570.0625	3585.0156
60	3600	3615.0156	3630.0625	3645.1406	3660.25	3675.3906	3690.5625	3705.7656
61	3721	3736.2656	3751.5625	3766.8906	3782.25	3797.6406	3813.0625	3828.5156
62	3844	3859.5156	3875.0625	3890.6406	3906.25	3921.8906	3937.5625	3953.2656
63	3969	3984.7656	4000.5625	4016.3906	4032.25	4048.1406	4064.0625	4080.0156
64	4096	4112.0156	4128.0625	4144.1406	4160.25	4176.3906	4192.5625	4208.7656
65	4225	4241.2656	4257.5625	4273.8906	4290.25	4306.6406	4323.0625	4339.5156
66	4356	4372.5156	4389.0625	4405.6406	4422.25	4438.8906	4455.5625	4472.2656
67	4489	4505.7656	4522.5625	4539.3906	4556.25	4573.1406	4590.0625	4607.0156
68	4624	4641.0156	4658.0625	4675.1406	4692.25	4709.3906	4726.5625	4743.7656
69	4761	4778.2656	4795.5625	4812.8906	4830.25	4847.6406	4865.0625	4882.5156
70	4900	4917.5156	4935.0625	4952.6406	4970.25	4987.8906	5005.5625	5023.2656

CUBES OF NUMBERS AND FRACTIONAL INTERVALS

Fraction	0	1	2	3	4	5
0	0.000000	1.000000	8.000000	27.000000	64.000000	125.000000
$\frac{1}{32}$	.030518	1.096710	8.380890	27.85257	65.51175	127.35843
$\frac{1}{16}$	.082397	1.199463	8.773682	28.72290	67.04712	129.74634
$\frac{3}{32}$	.156250	1.308441	9.178558	29.61118	68.60629	132.16391
$\frac{1}{8}$	.24414	1.423828	9.595703	30.51758	70.18945	134.61133
$\frac{5}{32}$	.33789	1.545807	10.025299	31.44229	71.79678	137.08878
$\frac{3}{16}$	.43750	1.674561	10.467529	32.38550	73.42847	139.59644
$\frac{7}{32}$	.54297	1.810272	10.922577	33.34738	75.08469	142.13449
$\frac{1}{4}$	.65625	1.953125	11.390625	34.32813	76.76563	144.70313
$\frac{9}{32}$	.77500	2.103302	11.871857	35.32791	78.47147	147.30252
$\frac{5}{16}$	.90000	2.260986	12.366455	36.34692	80.20239	149.93286
$\frac{11}{32}$	1.03125	2.426361	12.874603	37.38535	81.95859	152.59433
$\frac{3}{8}$	1.17969	2.599609	13.396484	38.44336	83.74023	155.28711
$\frac{13}{32}$	1.33789	2.780914	13.932281	39.52115	85.54752	158.01138
$\frac{7}{16}$	1.50597	2.970459	14.482178	40.61890	87.38062	160.76733
$\frac{15}{32}$	1.68438	3.168427	15.046356	41.73679	89.23972	163.55515
$\frac{1}{2}$	1.87500	3.375000	15.625000	42.87500	91.12500	166.37500
$\frac{17}{32}$	2.07812	3.590363	16.218292	44.03372	93.03665	169.22708
$\frac{9}{16}$	2.29688	3.814697	16.826416	45.21313	94.97485	172.11157
$\frac{19}{32}$	2.53125	4.048187	17.449554	46.41342	96.93979	175.02866
$\frac{5}{8}$	2.78125	4.291016	18.087891	47.63477	98.93164	177.97852
$\frac{21}{32}$	3.03789	4.543365	18.741608	48.87735	100.95059	180.96133
$\frac{11}{16}$	3.30625	4.805420	19.410889	50.14136	102.99683	183.97729
$\frac{23}{32}$	3.58750	5.077362	20.095917	51.42697	105.07053	187.02658
$\frac{3}{4}$	3.88125	5.359375	20.796875	52.73438	107.17188	190.10938
$\frac{25}{32}$	4.18750	5.651642	21.513947	54.06375	109.30106	193.22586
$\frac{13}{16}$	4.50625	5.954346	22.247314	55.41528	111.45825	196.37622
$\frac{27}{32}$	4.83750	6.267670	22.997162	56.78915	113.64365	199.56064
$\frac{7}{8}$	5.18125	6.591797	23.763672	58.18555	115.85742	202.77930
$\frac{29}{32}$	5.53789	6.926910	24.547028	59.60464	118.09976	206.03238
$\frac{15}{16}$	5.90625	7.273193	25.347412	61.04663	120.37085	209.32007
$\frac{31}{32}$	6.28750	7.630829	26.165009	62.51169	122.67087	212.64255
Fraction	6	7	8	9	10	11
0	216.00000	343.00000	512.00000	729.0000	1000.0000	1331.0000
$\frac{1}{32}$	219.39261	347.61429	518.02347	736.6201	1009.4043	1342.3760
$\frac{1}{16}$	222.82056	352.26978	524.09399	744.2932	1018.8674	1353.8167
$\frac{3}{32}$	226.28403	356.96664	530.21176	752.0194	1028.3895	1365.3221
$\frac{1}{8}$	229.78320	361.70508	536.37695	759.7988	1037.9707	1376.8926
$\frac{5}{32}$	233.31827	366.48526	542.58975	767.6317	1047.6112	1388.5282
$\frac{3}{16}$	236.88940	371.30737	548.85034	775.5183	1057.3113	1400.2292
$\frac{7}{32}$	240.49680	376.17160	555.15891	783.4587	1067.0710	1411.9958
$\frac{1}{4}$	244.14063	381.07813	561.51563	791.4531	1076.8906	1423.8281
$\frac{9}{32}$	247.82108	386.02713	567.92068	799.5017	1086.7703	1435.7263
$\frac{5}{16}$	251.53833	391.01880	574.37427	807.6047	1096.7102	1447.6907
$\frac{11}{32}$	255.29257	396.05331	580.87656	815.7623	1106.7105	1459.7213
$\frac{3}{8}$	259.08398	401.13086	587.42773	823.9746	1116.7715	1471.8184
$\frac{13}{32}$	262.91275	406.25162	594.02798	832.2418	1126.8932	1483.9821
$\frac{7}{16}$	266.77905	411.41577	600.67749	840.5642	1137.0759	1496.2126
$\frac{15}{32}$	270.68307	416.62350	607.37643	848.9419	1147.3198	1508.5102

CUBES OF NUMBERS AND FRACTIONAL INTERVALS

Fraction	6	7	8	9	10	11
----- $\frac{1}{2}$	274.62500	421.87500	614.12500	857.3750	1157.6250	1520.8750
$\frac{17}{32}$ -----	278.60501	427.17044	620.92337	865.8638	1167.9917	1533.3072
----- $\frac{9}{16}$	282.62329	432.51001	627.77173	874.4084	1178.4202	1545.8069
$\frac{19}{32}$ -----	286.68002	437.89389	634.67026	883.0091	1188.9105	1558.3774
----- $\frac{5}{8}$	290.77539	443.32227	641.61914	891.6660	1199.4629	1571.0098
$\frac{21}{32}$ -----	294.90958	448.79532	648.61856	900.3793	1210.0775	1583.7133
----- $\frac{11}{16}$	299.08276	454.31323	655.66870	909.1491	1220.7546	1596.4851
$\frac{23}{32}$ -----	303.29514	459.87619	662.76974	917.9758	1231.4943	1609.3254
----- $\frac{3}{4}$	307.54688	465.48438	669.92188	926.8594	1242.2969	1622.2344
$\frac{25}{32}$ -----	311.83817	471.13797	677.12527	935.8001	1253.1624	1635.2122
----- $\frac{13}{16}$	316.16919	476.83716	684.38013	944.7981	1264.0911	1648.2590
$\frac{27}{32}$ -----	320.54013	482.58212	691.68661	953.8536	1275.0831	1661.3751
----- $\frac{7}{8}$	324.95117	488.37305	699.04492	962.9668	1286.1387	1674.5605
$\frac{29}{32}$ -----	329.40250	494.21011	706.45523	972.1378	1297.2580	1687.8156
----- $\frac{15}{16}$	333.89429	500.09351	713.91772	981.3669	1308.4412	1701.1404
$\frac{31}{32}$ -----	338.42673	506.02341	721.43259	990.6543	1319.6884	1714.5351
Fraction	12	13	14	15	16	17
----- 0	1728.0000	2197.0000	2744.0000	3375.0000	4096.0000	4913.0000
$\frac{1}{16}$ -----	1755.1409	2228.8401	2780.9143	3417.3635	4144.1877	4967.3870
----- $\frac{1}{8}$	1782.5645	2260.9863	2818.1582	3460.0801	4192.7520	5022.1738
$\frac{3}{16}$ -----	1810.2722	2293.4402	2855.7332	3503.1511	4241.6941	5077.3621
----- $\frac{1}{4}$	1838.2656	2326.2031	2893.6406	3546.5781	4291.0156	5132.9531
$\frac{5}{16}$ -----	1866.5461	2359.2766	2931.8821	3590.3625	4340.7180	5188.9485
----- $\frac{3}{8}$	1895.1152	2392.6621	2970.4590	3634.5059	4390.8027	5245.3496
$\frac{7}{16}$ -----	1923.9744	2426.3611	3009.3728	3679.0095	4441.2712	5302.1580
----- $\frac{1}{2}$	1953.1250	2460.3750	3048.6250	3723.8750	4492.1250	5359.3750
$\frac{9}{16}$ -----	1982.5686	2494.7053	3088.2170	3769.1038	4543.3655	5417.0022
----- $\frac{5}{8}$	2012.3066	2529.3535	3128.1504	3814.6973	4594.9941	5475.0410
$\frac{11}{16}$ -----	2042.3406	2564.3210	3168.4265	3860.6570	4647.0125	5533.4929
----- $\frac{3}{4}$	2072.6719	2599.6094	3209.0469	3906.9844	4699.4219	5592.3594
$\frac{13}{16}$ -----	2103.3020	2635.2200	3250.0129	3953.6809	4752.2239	5651.6418
----- $\frac{7}{8}$	2134.2324	2671.1543	3291.3262	4000.7480	4805.4199	5711.3418
$\frac{15}{16}$ -----	2165.4646	2707.4138	3332.9880	4048.1873	4859.0115	5771.4607
Fraction	18	19	20	21	22	23
----- 0	5832.0000	6859.0000	8000.0000	9261.000	10648.000	12167.000
$\frac{1}{16}$ -----	5892.9612	6926.9104	8075.2346	9343.934	10739.008	12266.457
----- $\frac{1}{8}$	5954.3457	6995.2676	8150.9395	9427.361	10830.533	12366.455
$\frac{3}{16}$ -----	6016.1550	7064.0730	8227.1160	9511.284	10922.577	12466.995
----- $\frac{1}{4}$	6078.3906	7133.3281	8303.7656	9595.703	11015.141	12568.078
$\frac{5}{16}$ -----	6141.0540	7203.0344	8380.8899	9680.620	11108.226	12669.706
----- $\frac{3}{8}$	6204.1465	7273.1934	8458.4902	9766.037	11201.834	12771.881
$\frac{7}{16}$ -----	6267.6697	7343.8064	8536.5681	9851.955	11295.967	12874.603
----- $\frac{1}{2}$	6331.6250	7414.8750	8615.1250	9938.375	11390.625	12977.875
$\frac{9}{16}$ -----	6396.0139	7486.4006	8694.1624	10025.299	11485.811	13081.698
----- $\frac{5}{8}$	6460.8379	7558.3848	8773.6816	10112.729	11581.525	13186.072
$\frac{11}{16}$ -----	6526.0984	7630.8289	8853.6843	10200.665	11677.770	13291.001
----- $\frac{3}{4}$	6591.7969	7703.7344	8934.1719	10289.109	11774.547	13396.484
$\frac{13}{16}$ -----	6657.9348	7777.1028	9015.1458	10378.064	11871.857	13502.525
----- $\frac{7}{8}$	6724.5137	7850.9355	9096.6074	10467.529	11969.701	13609.123
$\frac{15}{16}$ -----	6791.5349	7925.2341	9178.5583	10557.508	12068.082	13716.281

CUBES OF NUMBERS AND FRACTIONAL INTERVALS

No.	0	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
24	13824	14041.127	14260.516	14482.178	14706.125	14932.369	15160.922	15391.796
25	15625	15860.549	16098.453	16338.725	16581.375	16826.416	17073.859	17323.717
26	17576	17830.721	18087.891	18347.521	18609.625	18874.213	19141.297	19410.889
27	19683	19957.643	20234.828	20514.568	20796.875	21081.760	21369.234	21659.311
28	21952	22247.315	22545.266	22845.865	23149.125	23455.057	23763.672	24074.982
29	24389	24705.736	25025.203	25347.412	25672.375	26000.104	26330.609	26663.904
30	27000	27338.908	27680.641	28025.209	28372.625	28722.900	29076.047	29432.076
31	29791	30152.830	30517.578	30885.256	31255.875	31629.447	32005.984	32385.498
32	32768	33153.502	33542.016	33933.553	34328.125	34725.744	35126.422	35530.170
33	35937	36346.924	36759.953	37176.100	37595.375	38017.791	38443.359	38872.092
34	39304	39739.096	40177.391	40618.896	41063.625	41511.588	41962.797	42417.264
35	42875	43336.018	43800.328	44267.943	44738.875	45213.135	45690.734	46171.686
36	46656	47143.689	47634.766	48129.240	48627.125	49128.432	49633.172	50141.357
37	50653	51168.111	51686.703	52208.787	52734.375	53263.479	53796.109	54332.279
38	54872	55415.283	55962.141	56512.584	57066.625	57624.275	58185.547	58750.451
39	59319	59891.205	60467.078	61046.631	61629.875	62216.822	62807.484	63401.873
40	64000	64601.877	65207.516	65816.928	66430.125	67047.119	67667.922	68292.545
41	68921	69553.299	70189.453	70829.475	71473.375	72121.166	72772.859	73428.467
42	74088	74751.471	75418.891	76090.272	76765.625	77444.963	78128.297	78815.639
43	79507	80202.393	80901.828	81605.318	82312.875	83024.510	83740.234	84460.061
44	85184	85912.065	86644.266	87380.615	88121.125	88865.807	89614.672	90367.732
45	91125	91886.486	92652.203	93422.162	94196.375	94974.854	95757.609	96544.654
46	97336	98131.658	98931.641	99735.959	100544.63	101357.65	102175.05	102996.83
47	103823	104653.58	105488.58	106328.01	107171.87	108020.20	108872.98	109730.25
48	110592	111458.25	112329.02	113204.30	114084.12	114968.49	115857.42	116750.92
49	117649	118551.67	119458.95	120370.85	121287.37	122208.54	123134.36	124064.84
50	125000	125939.85	126884.39	127833.65	128787.62	129746.34	130709.80	131678.01
51	132651	133628.77	134611.33	135598.69	136590.87	137587.88	138589.73	139596.44
52	140608	141624.44	142645.77	143671.99	144703.12	145739.18	146780.17	147826.11
53	148877	149932.86	150993.70	152059.54	153130.37	154206.23	155287.11	156373.03
54	157464	158560.03	159661.14	160767.33	161878.62	162995.03	164116.55	165243.20
55	166375	167511.96	168654.08	169801.38	170953.87	172111.57	173274.48	174442.62
56	175616	176794.63	177978.52	179167.68	180362.12	181561.87	182766.92	183977.29
57	185193	186414.05	187640.45	188872.22	190109.37	191351.92	192599.86	193853.22
58	196112	196376.22	197645.89	198921.02	200201.62	201487.71	202779.30	204076.39
59	205379	206687.14	208000.83	209320.07	210644.87	211975.26	213311.23	214652.81
60	216000	217352.81	218711.27	220075.37	221445.12	222820.56	224201.67	225588.48
61	226981	228379.24	229783.20	231192.91	232608.38	234029.60	235456.61	236889.40
62	238328	239772.41	241222.64	242678.71	244140.63	245608.40	247082.05	248561.58
63	250047	251538.33	253035.58	254538.76	256047.88	257562.95	259083.98	260611.00
64	262144	263683.00	265228.02	266779.05	268336.13	269899.24	271468.42	273043.67
65	274625	276212.42	277805.95	279405.60	281011.38	282623.29	284241.36	285865.59
66	287496	289132.60	290775.39	292424.40	294079.63	295741.09	297408.80	299082.76
67	300763	302449.52	304142.33	305841.44	307546.88	309258.63	310976.73	312701.19
68	314432	316169.19	317912.77	319662.74	321419.13	323181.93	324951.17	326726.86
69	328509	330297.61	332092.70	333894.29	335702.37	337516.98	339338.11	341165.78
70	343000	344840.78	346688.14	348542.08	350402.61	352269.77	354143.55	356023.95

DECIMAL EQUIVALENTS OF NON-BINARY FRACTIONS

(DENOMINATORS 7 TO 19)

Numerator	DENOMINATOR									
	7	9	11	12	13	14	15	17	18	19
1	.1429	.1111	.0909	.0833	.0769	.0714	.0667	.0588	.0556	.0526
2	.2857	.2222	.1818	.1667	.1538	.1429	.1333	.1176	.1111	.1053
3	.4286	.3333	.2727	.2500	.2308	.2143	.2000	.1765	.1667	.1579
4	.5714	.4444	.3636	.3333	.3077	.2857	.2667	.2353	.2222	.2105
5	.7143	.5556	.4545	.4167	.3846	.3571	.3333	.2941	.2778	.2632
6	.8571	.6667	.5455	.5000	.4615	.4286	.4000	.3529	.3333	.3158
7	-----	.7778	.6364	.5833	.5385	.5000	.4667	.4118	.3889	.3684
8	-----	.8889	.7273	.6667	.6154	.5714	.5333	.4706	.4444	.4211
9	-----	-----	.8182	.7500	.6923	.6429	.6000	.5294	.5000	.4737
10	-----	-----	.9091	.8333	.7692	.7143	.6667	.5882	.5556	.5263
11	-----	-----	-----	.9167	.8462	.7857	.7333	.6471	.6111	.5789
12	-----	-----	-----	-----	.9231	.8571	.8000	.7059	.6667	.6316
13	-----	-----	-----	-----	-----	.9286	.8667	.7647	.7222	.6842
14	-----	-----	-----	-----	-----	-----	.9333	.8235	.7778	.7368
15	-----	-----	-----	-----	-----	-----	-----	.8824	.8333	.7895
16	-----	-----	-----	-----	-----	-----	-----	.9412	.8889	.8421
17	-----	-----	-----	-----	-----	-----	-----	-----	.9444	.8947
18	-----	-----	-----	-----	-----	-----	-----	-----	-----	.9474

SQUARE ROOTS AND CUBE ROOTS OF FRACTIONS

Fraction	Square Root	Cube Root	Fraction	Square Root	Cube Root	Fraction	Square Root	Cube Root
$\frac{1}{2}$	.70711	.79370	$\frac{6}{7}$	.92582	.94991	$\frac{1}{12}$	.28868	.43679
$\frac{1}{3}$	.57735	.69336	$\frac{1}{8}$	.35355	.50000	$\frac{5}{12}$	.64550	.74690
$\frac{2}{3}$	.81650	.87358	$\frac{3}{8}$	.61237	.72112	$\frac{7}{12}$	.76376	.83555
$\frac{1}{4}$	.50000	.62996	$\frac{5}{8}$	.79057	.85499	$\frac{11}{12}$	.95743	.97141
$\frac{3}{4}$	.86603	.90856	$\frac{7}{8}$	.93541	.95647	$\frac{1}{16}$	.25000	.39685
$\frac{1}{6}$	.40825	.55032	$\frac{1}{9}$	.33333	.48075	$\frac{3}{16}$	.43301	.57236
$\frac{5}{6}$	.91287	.94104	$\frac{2}{9}$	.47140	.60571	$\frac{5}{16}$	.55902	.67860
$\frac{1}{7}$	.37796	.52275	$\frac{4}{9}$	.66667	.76314	$\frac{7}{16}$	.66144	.75915
$\frac{2}{7}$	.53452	.65863	$\frac{5}{9}$	.74536	.82207	$\frac{9}{16}$	.75000	.82548
$\frac{3}{7}$	.65465	.75395	$\frac{7}{9}$	.88192	.91963	$\frac{11}{16}$	.82916	.88259
$\frac{4}{7}$	.75593	.82983	$\frac{8}{9}$	.94281	.96150	$\frac{13}{16}$	.90138	.93313
$\frac{5}{7}$	.84515	.89390	---	-----	-----	$\frac{15}{16}$	.96825	.97872

DECIMAL EQUIVALENTS OF NON-BINARY FRACTIONS

(DENOMINATORS 21 TO 31)

Numerator	DENOMINATOR									
	21	22	23	24	26	27	28	29	30	31
1	.0476	.0455	.0435	.0417	.0385	.0370	.0357	.0345	.0333	.0323
2	.0952	.0909	.0870	.0833	.0769	.0741	.0714	.0690	.0667	.0645
3	.1429	.1364	.1304	.1250	.1154	.1111	.1071	.1034	.1000	.0968
4	.1905	.1818	.1739	.1667	.1538	.1481	.1429	.1379	.1333	.1290
5	.2381	.2273	.2174	.2083	.1923	.1852	.1786	.1724	.1667	.1613
6	.2857	.2727	.2609	.2500	.2308	.2222	.2143	.2069	.2000	.1935
7	.3333	.3182	.3043	.2917	.2692	.2593	.2500	.2414	.2333	.2258
8	.3810	.3636	.3478	.3333	.3077	.2963	.2857	.2759	.2667	.2581
9	.4286	.4091	.3913	.3750	.3462	.3333	.3214	.3103	.3000	.2903
10	.4762	.4545	.4348	.4167	.3846	.3704	.3571	.3448	.3333	.3226
11	.5238	.5000	.4783	.4583	.4231	.4074	.3929	.3793	.3667	.3548
12	.5714	.5455	.5217	.5000	.4615	.4444	.4286	.4138	.4000	.3871
13	.6190	.5909	.5652	.5417	.5000	.4815	.4643	.4483	.4333	.4194
14	.6667	.6364	.6087	.5833	.5385	.5185	.5000	.4828	.4667	.4516
15	.7143	.6818	.6522	.6250	.5769	.5555	.5357	.5172	.5000	.4839
16	.7619	.7273	.6957	.6667	.6154	.5926	.5714	.5517	.5333	.5161
17	.8095	.7727	.7391	.7083	.6538	.6296	.6071	.5862	.5667	.5484
18	.8571	.8182	.7826	.7500	.6923	.6667	.6429	.6207	.6000	.5806
19	.9048	.8636	.8261	.7917	.7308	.7037	.6786	.6552	.6333	.6129
20	.9524	.9091	.8696	.8333	.7692	.7407	.7143	.6897	.6667	.6452
21	-----	.9545	.9130	.8750	.8077	.7778	.7500	.7241	.7000	.6774
22	-----	-----	.9565	.9167	.8462	.8148	.7857	.7586	.7333	.7097
23	-----	-----	-----	.9583	.8846	.8519	.8214	.7931	.7667	.7419
24	-----	-----	-----	-----	.9231	.8889	.8571	.8276	.8000	.7742
25	-----	-----	-----	-----	.9615	.9259	.8929	.8621	.8333	.8065
26	-----	-----	-----	-----	-----	.9630	.9286	.8966	.8667	.8387
27	-----	-----	-----	-----	-----	-----	.9643	.9310	.9000	.8710
28	-----	-----	-----	-----	-----	-----	-----	.9655	.9333	.9032
29	-----	-----	-----	-----	-----	-----	-----	-----	.9667	.9355
30	-----	-----	-----	-----	-----	-----	-----	-----	-----	.9677

TEMPERATURE CONVERSION TABLES

Albert Sauveur type of table. Values revised.

-459.4 to 0			0 to 100						100 to 1000					
C	C	F	C	C	F	C	C	F	C	C	F	C	C	F
-273	-459.4		-17.8	0	32	10.0	50	122.0	38	100	212	260	500	932
-268	-450		-17.2	1	33.8	10.6	51	123.8	43	110	230	266	510	950
-262	-440		-16.7	2	35.6	11.1	52	125.6	49	120	248	271	520	968
-257	-430		-16.1	3	37.4	11.7	53	127.4	54	130	266	277	530	986
-251	-420		-15.6	4	39.2	12.2	54	129.2	60	140	284	282	540	1004
-246	-410		-15.0	5	41.0	12.8	55	131.0	66	150	302	288	550	1022
-240	-400		-14.4	6	42.8	13.3	56	132.8	71	160	320	293	560	1040
-234	-390		-13.9	7	44.6	13.9	57	134.6	77	170	338	299	570	1058
-229	-380		-13.3	8	46.4	14.4	58	136.4	82	180	356	304	580	1076
-223	-370		-12.8	9	48.2	15.0	59	138.2	88	190	374	310	590	1094
-218	-360		-12.2	10	50.0	15.6	60	140.0	93	200	392	316	600	1112
-212	-350		-11.7	11	51.8	16.1	61	141.8	99	210	410	321	610	1130
-207	-340		-11.1	12	53.6	16.7	62	143.6	100	212	413.6	327	620	1148
-201	-330		-10.6	13	55.4	17.2	63	145.4	104	220	428	332	630	1166
-196	-320		-10.0	14	57.2	17.8	64	147.2	110	230	446	338	640	1184
-190	-310		-9.4	15	59.0	18.3	65	149.0	116	240	464	343	650	1202
-184	-300		-8.9	16	60.8	18.9	66	150.8	121	250	482	349	660	1220
-179	-290		-8.3	17	62.6	19.4	67	152.6	127	260	500	354	670	1238
-173	-280		-7.8	18	64.4	20.0	68	154.4	132	270	518	360	680	1256
-169	-273	-459.4	-7.2	19	66.2	20.6	69	156.2	138	280	536	366	690	1274
-168	-270	-454	-6.7	20	68.0	21.1	70	158.0	143	290	554	371	700	1292
-162	-260	-436	-6.1	21	69.8	21.7	71	159.8	149	300	572	377	710	1310
-157	-250	-418	-5.6	22	71.6	22.2	72	161.6	154	310	590	382	720	1328
-151	-240	-400	-5.0	23	73.4	22.8	73	163.4	160	320	608	388	730	1346
-146	-230	-382	-4.4	24	75.2	23.3	74	165.2	166	330	626	393	740	1364
-140	-220	-364	-3.9	25	77.0	23.9	75	167.0	171	340	644	399	750	1382
-134	-210	-346	-3.3	26	78.8	24.4	76	168.8	177	350	662	404	760	1400
-129	-200	-328	-2.8	27	80.6	25.0	77	170.6	182	360	680	410	770	1418
-123	-190	-310	-2.2	28	82.4	25.6	78	172.4	188	370	698	416	780	1436
-118	-180	-292	-1.7	29	84.2	26.1	79	174.2	193	380	716	421	790	1454
-112	-170	-274	-1.1	30	86.0	26.7	80	176.0	199	390	734	427	800	1472
-107	-160	-256	-.6	31	87.8	27.2	81	177.8	204	400	752	432	810	1490
-101	-150	-238	0	32	89.6	27.8	82	179.6	210	410	770	438	820	1508
-96	-140	-220	0	33	91.4	28.3	83	181.4	216	420	788	443	830	1526
-90	-130	-202	1.1	34	93.2	28.9	84	183.2	221	430	806	449	840	1544
-84	-120	-184	1.7	35	95.0	29.4	85	185.0	227	440	824	454	850	1562
-79	-110	-166	2.2	36	96.8	30.0	86	186.8	232	450	842	460	860	1580
-73	-100	-148	2.8	37	98.6	30.6	87	188.6	238	460	860	466	870	1598
-68	-90	-130	3.3	38	100.4	31.1	88	190.4	243	470	878	471	880	1616
-62	-80	-112	3.9	39	102.2	31.7	89	192.2	249	480	896	477	890	1634
-57	-70	-94	4.4	40	104.0	32.2	90	194.0	254	490	914	482	900	1652
-51	-60	-76	5.0	41	105.8	32.8	91	195.8				488	910	1670
-46	-50	-58	5.6	42	107.6	33.3	92	197.6				493	920	1688
-40	-40	-40	6.1	43	109.4	33.9	93	199.4				499	930	1706
-34	-30	-22	6.7	44	111.2	34.4	94	201.2				504	940	1724
-29	-20	-4	7.2	45	113.0	35.0	95	203.0				510	950	1742
-23	-10	14	7.8	46	114.8	35.6	96	204.8				516	960	1760
-17.8	0	32	8.3	47	116.6	36.1	97	206.6				521	970	1778
			8.9	48	118.4	36.7	98	208.4				527	980	1796
			9.4	49	120.2	37.2	99	210.2				532	990	1814
						37.8	100	212.0				538	1000	1832

Look up reading in middle column. If in degrees Centigrade, read Fahrenheit equivalent in right hand column; if in Fahrenheit degrees, read Centigrade equivalent in left hand column.

TEMPERATURE CONVERSION TABLES

Albert Sauveur type of table. Values revised.

1000 to 2000						2000 to 3000					
C	C	F	C	F	F	C	C	F	C	F	F
538	1000	1832	816	1500	2732	1093	2000	3632	1371	2500	4532
543	1010	1850	821	1510	2750	1099	2010	3650	1377	2510	4550
549	1020	1868	827	1520	2768	1104	2020	3668	1382	2520	4568
554	1030	1886	832	1530	2786	1110	2030	3686	1388	2530	4586
560	1040	1904	838	1540	2804	1116	2040	3704	1393	2540	4604
566	1050	1922	843	1550	2822	1121	2050	3722	1399	2550	4622
571	1060	1940	849	1560	2840	1127	2060	3740	1404	2560	4640
577	1070	1958	854	1570	2858	1132	2070	3758	1410	2570	4658
582	1080	1976	860	1580	2876	1138	2080	3776	1416	2580	4676
588	1090	1994	866	1590	2894	1143	2090	3794	1421	2590	4694
593	1100	2012	871	1600	2912	1149	2100	3812	1427	2600	4712
599	1110	2030	877	1610	2930	1154	2110	3830	1432	2610	4730
604	1120	2048	882	1620	2948	1160	2120	3848	1438	2620	4748
610	1130	2066	888	1630	2966	1166	2130	3866	1443	2630	4766
616	1140	2084	893	1640	2984	1171	2140	3884	1449	2640	4784
621	1150	2102	899	1650	3002	1177	2150	3902	1454	2650	4802
627	1160	2120	904	1660	3020	1182	2160	3920	1460	2660	4820
632	1170	2138	910	1670	3038	1188	2170	3938	1466	2670	4838
638	1180	2156	916	1680	3056	1193	2180	3956	1471	2680	4856
643	1190	2174	921	1690	3074	1199	2190	3974	1477	2690	4874
649	1200	2192	927	1700	3092	1204	2200	3992	1482	2700	4892
654	1210	2210	932	1710	3110	1210	2210	4010	1488	2710	4910
660	1220	2228	938	1720	3128	1216	2220	4028	1493	2720	4928
666	1230	2246	943	1730	3146	1221	2230	4046	1499	2730	4946
671	1240	2264	949	1740	3164	1227	2240	4064	1504	2740	4964
677	1250	2282	954	1750	3182	1232	2250	4082	1510	2750	4982
682	1260	2300	960	1760	3200	1238	2260	4100	1516	2760	5000
688	1270	2318	966	1770	3218	1243	2270	4118	1521	2770	5018
693	1280	2336	971	1780	3236	1249	2280	4136	1527	2780	5036
699	1290	2354	977	1790	3254	1254	2290	4154	1532	2790	5054
704	1300	2372	982	1800	3272	1260	2300	4172	1538	2800	5072
710	1310	2390	988	1810	3290	1266	2310	4190	1543	2810	5090
716	1320	2408	993	1820	3308	1271	2320	4208	1549	2820	5108
721	1330	2426	999	1830	3326	1277	2330	4226	1554	2830	5126
727	1340	2444	1004	1840	3344	1282	2340	4244	1560	2840	5144
732	1350	2462	1010	1850	3362	1288	2350	4262	1566	2850	5162
738	1360	2480	1016	1860	3380	1293	2360	4280	1571	2860	5180
743	1370	2498	1021	1870	3398	1299	2370	4298	1577	2870	5198
749	1380	2516	1027	1880	3416	1304	2380	4316	1582	2880	5216
754	1390	2534	1032	1890	3434	1310	2390	4334	1588	2890	5234
760	1400	2552	1038	1900	3452	1316	2400	4352	1593	2900	5252
766	1410	2570	1043	1910	3470	1321	2410	4370	1599	2910	5270
771	1420	2588	1049	1920	3488	1327	2420	4388	1604	2920	5288
777	1430	2606	1054	1930	3506	1332	2430	4406	1610	2930	5306
782	1440	2624	1060	1940	3524	1338	2440	4424	1616	2940	5324
788	1450	2642	1066	1950	3542	1343	2450	4442	1621	2950	5342
793	1460	2660	1071	1960	3560	1349	2460	4460	1627	2960	5360
799	1470	2678	1077	1970	3578	1354	2470	4478	1632	2970	5378
804	1480	2696	1082	1980	3596	1360	2480	4496	1638	2980	5396
810	1490	2714	1088	1990	3614	1366	2490	4514	1643	2990	5414
			1093	2000	3632				1649	3000	5432

Look up reading in middle column. If in degrees Centigrade, read Fahrenheit equivalent in right hand column; if in degrees Fahrenheit, read Centigrade equivalent in left hand column.

HARDNESS CONVERSION TABLE

Brinell (3000 Kg.)		Rockwell		Shore	Vickers	Tensile Strength
Diam.	Number	C	B			
2.20	780	68	-----	100	1185	-----
2.25	745	67	-----	97	1087	-----
2.30	712	66	-----	94	990	-----
2.35	682	64	-----	90	928	-----
2.40	653	63	-----	87	867	-----
2.45	627	62	-----	83	803	-----
2.50	601	60	-----	80	746	295,900
2.55	578	58	-----	77	694	284,300
2.60	555	56	-----	74	649	273,300
2.65	534	55	-----	72	606	262,900
2.70	514	53	-----	69	587	253,100
2.75	495	52	-----	67	551	243,800
2.80	477	50	-----	65	534	235,000
2.85	461	48	-----	62	502	226,600
2.90	444	46	-----	59	474	218,700
2.95	429	44	-----	56	460	211,200
3.00	415	42	-----	54	435	204,100
3.05	401	41	-----	52	423	197,300
3.10	388	39	-----	50	401	190,800
3.15	375	38	-----	49	390	184,600
3.20	363	37	-----	47	380	178,800
3.25	352	36	-----	46	361	173,200
3.30	341	35	-----	45	344	167,800
3.35	331	34	-----	44	335	162,700
3.40	321	33	-----	43	320	157,800
3.45	311	32	-----	42	312	152,100
3.50	302	31	106	41	305	148,600
3.55	293	30	105	40	291	144,300
3.60	285	29	104	39	285	140,200
3.65	277	28	103	38	278	136,200
3.70	269	27	102.5	37	272	132,400
3.75	262	26	102	36	261	128,800
3.80	255	25	101	35	255	125,300
3.85	248	24	100	34	250	121,900
3.90	241	23	99.5	33	240	118,700
3.95	235	22	99	32	235	115,500
4.00	229	21	98	31	226	112,000
4.05	223	20	97	30	221	109,700
4.10	217	19	96	29	217	106,900
4.15	212	18	95.5	28	213	104,200
4.20	207	17	94.5	27	209	101,600
4.25	201	16	93.5	26	-----	99,100
4.30	197	15	93	25	-----	96,700
4.35	192	14	92	24	-----	94,400
4.40	187	12	91	23	-----	92,200
4.45	183	11	90	22	-----	90,000
4.50	179	10	88	21	-----	87,900
4.55	174	-----	87	20	-----	85,800
4.60	170	-----	86	19	-----	83,900
4.65	167	-----	85	19	-----	82,000
4.70	163	-----	84	18	-----	80,100
4.75	159	-----	83	18	-----	78,300
4.80	156	-----	82	18	-----	76,600
4.85	152	-----	81	17	-----	74,900
4.90	149	-----	80	17	-----	73,300

HARDNESS CONVERSION TABLE

Brinell (3000 Kg.)		Rockwell		Shore	Vickers	Tensile Strength
Diam.	Number	C	B			
4.95	146	.....	79	17	.....	71,000
5.00	143	.....	77	17	.....	70,200
5.05	140	.....	76	16	.....	69,400
5.10	137	.....	75	16	.....	67,800
5.15	134	.....	74	16	.....	66,300
5.20	131	.....	72	16	.....	64,800
5.25	128	.....	71	16	.....	63,300
5.30	126	.....	70	15	.....	62,300
5.35	123	.....	69	15	.....	61,900
5.40	121	.....	68	15	.....	59,900
5.45	118	.....	67	.....	.....	58,500
5.50	116	.....	66	.....	.....	57,400
5.55	114	.....	64	.....	.....	56,600
5.60	112	.....	63	.....	.....	55,800
5.65	109	.....	62	.....	.....	54,900
5.70	107	.....	60	.....	.....	54,100
5.75	105	.....	58	.....	.....	53,300
5.80	103	.....	57	.....	.....	52,400
5.85	101	.....	56	.....	.....	51,600
5.90	99	.....	55	.....	.....	50,700
5.95	97	.....	53	.....	.....	49,900
6.00	95	.....	51	.....	.....	49,000
*	93	.....	50	.....	.....	.....
.....	92	.....	49	.....	.....	.....
.....	90	.....	48	.....	.....	.....
.....	88	.....	47	.....	.....	.....
.....	87	.....	46	.....	.....	.....
.....	86	.....	45	.....	.....	.....
.....	85	.....	44	.....	.....	.....
.....	83	.....	43	.....	.....	.....
.....	82	.....	42	.....	.....	.....
.....	81	.....	41	.....	.....	.....
.....	80	.....	40	.....	.....	.....
.....	79	.....	39	.....	.....	.....
.....	78	.....	38	.....	.....	.....
.....	77	.....	37	.....	.....	.....
.....	76	.....	36	.....	.....	.....
.....	75	.....	35	.....	.....	.....
.....	74	.....	33	.....	.....	.....
.....	73	.....	31	.....	.....	.....
.....	72	.....	30	.....	.....	.....

The hardness values are from tests taken on machined tensile test bars cut from 1-inch round or larger stock in the as-rolled, annealed, normalized, or quenched and drawn conditions. They give direct relation between hardness and tensile strength and are not affected by surface decarburization, skin hardness, surface cold work and other factors which influence the values of hardness tests taken on the original bar surface.

The Shore or scleroscope values vary over a wider range as compared with the tensile strength, than do the other measures of hardness. This is due to the influence of the elastic limit in this determination.

*Use 500 or 1000 kg. load.

This table will be found to be approximately correct. It cannot cover all conditions since size, shape, mass and other variables affect the above properties and their relationship.

BRINELL HARDNESS NUMERALS

Diam.	Kg. 5000	Kg. 3000	Kg. 1000	Kg. 500	Diam.	Kg. 5000	Kg. 3000	Kg. 1000	Kg. 500
2.00	1575	945	315	158	4.50	298	179	59.5	29.8
2.05	1499	899	300	150	4.55	291	174	58.1	29.1
2.10	1427	856	285	143	4.60	284	170	56.8	28.4
2.15	1361	817	272	136	4.65	278	167	55.8	27.8
2.20	1299	780	260	130	4.70	271	163	54.3	27.1
2.25	1241	745	248	124	4.75	265	159	53.0	26.5
2.30	1187	712	237	119	4.80	259	156	51.9	25.9
2.35	1137	682	227	114	4.85	254	152	50.7	25.4
2.40	1089	653	218	109	4.90	248	149	49.6	24.8
2.45	1044	627	209	104	4.95	243	146	48.6	24.3
2.50	1002	601	200	100	5.00	238	143	47.5	23.8
2.55	963	578	193	96.3	5.05	233	140	46.5	23.3
2.60	926	555	185	92.6	5.10	228	137	45.5	22.8
2.65	890	534	178	89.0	5.15	223	134	44.6	22.3
2.70	857	514	171	85.7	5.20	218	131	43.7	21.8
2.75	826	495	165	82.6	5.25	214	128	42.8	21.4
2.80	796	477	159	79.6	5.30	209	126	41.9	20.9
2.85	768	461	154	76.8	5.35	205	123	41.0	20.5
2.90	741	444	148	74.1	5.40	201	121	40.2	20.1
2.95	715	429	143	71.5	5.45	197	118	39.4	19.7
3.00	691	415	138	69.1	5.50	193	116	38.6	19.3
3.05	668	401	134	66.8	5.55	189	114	37.9	18.9
3.10	646	388	129	64.6	5.60	186	111	37.1	18.6
3.15	625	375	125	62.5	5.65	182	109	36.4	18.2
3.20	605	363	121	60.5	5.70	178	107	35.7	17.8
3.25	586	352	117	58.6	5.75	175	105	35.0	17.5
3.30	568	341	114	56.8	5.80	172	103	34.3	17.2
3.35	551	331	110	55.1	5.85	168	101	33.7	16.8
3.40	534	321	107	53.4	5.90	165	99.2	33.1	16.5
3.45	518	311	104	51.8	5.95	162	97.3	32.4	16.2
3.50	503	302	101	50.3	6.00	159	95.5	31.8	15.9
3.55	489	293	97.7	48.9	6.05	156	93.7	31.2	15.6
3.60	475	285	94.9	47.5	6.10	153	92.0	30.7	15.3
3.65	461	277	92.3	46.1	6.15	151	90.3	30.1	15.1
3.70	449	269	89.7	44.9	6.20	148	88.7	29.6	14.8
3.75	436	262	87.2	43.6	6.25	145	87.1	29.0	14.5
3.80	424	255	84.9	42.4	6.30	142	85.5	28.5	14.2
3.85	413	248	82.6	41.3	6.35	140	84.0	28.0	14.0
3.90	402	241	80.4	40.2	6.40	137	82.5	27.5	13.7
3.95	391	235	78.3	39.1	6.45	135	81.0	27.0	13.5
4.00	381	229	76.3	38.1	6.50	133	79.6	26.5	13.3
4.05	371	223	74.3	37.1	6.55	130	78.2	26.1	13.0
4.10	362	217	72.4	36.2	6.60	128	76.8	25.6	12.8
4.15	353	212	70.6	35.3	6.65	126	75.4	25.1	12.6
4.20	344	207	68.8	34.4	6.70	124	74.1	24.7	12.4
4.25	336	201	67.1	33.6	6.75	121	72.8	24.3	12.1
4.30	328	197	65.5	32.8	6.80	119	71.6	23.9	11.9
4.35	320	192	63.9	32.0	6.85	117	70.4	23.5	11.7
4.40	312	187	62.4	31.2	6.90	115	69.1	23.0	11.5
4.45	305	183	60.9	30.5	6.95	113	68.0	22.7	11.3
					7.00	111	66.8	22.3	11.1

Note: For other pressures the hardness numbers are in proportion to those given in the table; e. g., for 200 kg. are 1/5 of those for 1000 kg., etc.

DECIMALS OF A FOOT
FOR EACH 32ND OF AN INCH

Inch	0"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"
0	0	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
$\frac{1}{32}$	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193
$\frac{1}{16}$	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
$\frac{3}{32}$	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245
$\frac{1}{8}$	.0104	.0938	.1771	.2604	.3438	.4271	.5104	.5938	.6771	.7604	.8438	.9271
$\frac{5}{32}$	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297
$\frac{3}{16}$	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
$\frac{7}{32}$	.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349
$\frac{1}{4}$	.0208	.1042	.1875	.2708	.3542	.4375	.5203	.6042	.6875	.7708	.8542	.9375
$\frac{9}{32}$	.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6068	.6901	.7734	.8568	.9401
$\frac{5}{16}$	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
$\frac{11}{32}$	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453
$\frac{3}{8}$	.0313	.1146	.1979	.2812	.3646	.4479	.5313	.6146	.6979	.7813	.8646	.9479
$\frac{13}{32}$	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7005	.7839	.8672	.9505
$\frac{7}{16}$	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
$\frac{15}{32}$	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557
$\frac{1}{2}$	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
$\frac{17}{32}$	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609
$\frac{9}{16}$	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
$\frac{19}{32}$	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661
$\frac{5}{8}$	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
$\frac{21}{32}$	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714
$\frac{11}{16}$	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
$\frac{23}{32}$	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766
$\frac{3}{4}$	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
$\frac{25}{32}$	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	.9818
$\frac{13}{16}$	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
$\frac{27}{32}$	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870
$\frac{7}{8}$	.0729	.1563	.2396	.3229	.4063	.4896	.5729	.6563	.7396	.8229	.9063	.9896
$\frac{29}{32}$	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	.9922
$\frac{15}{16}$	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
$\frac{31}{32}$	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974

DECIMALS OF AN INCH FOR EACH 64TH

WITH MILLIMETER EQUIVALENTS

Fraction	$\frac{1}{64}$ ths	Decimal	Millimeters	Fraction	$\frac{1}{64}$ ths	Decimal	Millimeters
----	1	.015625	0.39688	----	33	.515625	13.09690
$\frac{1}{32}$	2	.03125	0.79375	$\frac{17}{32}$	34	.53125	13.49378
----	3	.046875	1.19063	----	35	.546875	13.89065
$\frac{1}{16}$	4	.0625	1.58750	$\frac{9}{16}$	36	.5625	14.28753
----	5	.078125	1.98438	----	37	.578125	14.68440
$\frac{3}{32}$	6	.09375	2.38125	$\frac{19}{32}$	38	.59375	15.08128
----	7	.109375	2.77813	----	39	.609375	15.47816
$\frac{1}{8}$	8	.125	3.17501	$\frac{5}{8}$	40	.625	15.87503
----	9	.140625	3.57188	----	41	.640625	16.27191
$\frac{5}{32}$	10	.15625	3.96876	$\frac{21}{32}$	42	.65625	16.66878
----	11	.171875	4.36563	----	43	.671875	17.06566
$\frac{3}{16}$	12	.1875	4.76251	$\frac{11}{16}$	44	.6875	17.46253
----	13	.203125	5.15939	----	45	.703125	17.85941
$\frac{7}{32}$	14	.21875	5.55626	$\frac{23}{32}$	46	.71875	18.25629
----	15	.234375	5.95314	----	47	.734375	18.65316
$\frac{1}{4}$	16	.25	6.35001	$\frac{3}{4}$	48	.75	19.05004
----	17	.265625	6.74689	----	49	.765625	19.44691
$\frac{9}{32}$	18	.28125	7.14376	$\frac{25}{32}$	50	.78125	19.84379
----	19	.296875	7.54064	----	51	.796875	20.24067
$\frac{5}{16}$	20	.3125	7.93752	$\frac{13}{16}$	52	.8125	20.63754
----	21	.328125	8.33439	----	53	.828125	21.03442
$\frac{11}{32}$	22	.34375	8.73127	$\frac{27}{32}$	54	.84375	21.43129
----	23	.359375	9.12814	----	55	.859375	21.82817
$\frac{3}{8}$	24	.375	9.52502	$\frac{7}{8}$	56	.875	22.22504
----	25	.390625	9.92189	----	57	.890625	22.62192
$\frac{13}{32}$	26	.40625	10.31877	$\frac{29}{32}$	58	.90625	23.01880
----	27	.421875	10.71565	----	59	.921875	23.41567
$\frac{7}{16}$	28	.4375	11.11252	$\frac{15}{16}$	60	.9375	23.81255
----	29	.453125	11.50940	----	61	.953125	24.20942
$\frac{15}{32}$	30	.46875	11.90627	$\frac{31}{32}$	62	.96875	24.60630
----	31	.484375	12.30315	----	63	.984375	25.00318
$\frac{1}{2}$	32	.5	12.70003	1	64	1.	25.40005

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Yield strength	177

BETHLEHEM STEEL COMPANY

BETHLEHEM, PA.

PARTIAL LIST OF PRODUCTS

AGRICULTURAL STEEL AND SPECIALTIES—Standard and special shapes and sections for all purposes; semi-finished agricultural implement parts.

ALLOY STEELS—Open hearth and electric furnace steels for all purposes; hot-rolled, cold-drawn, rough-turned or ground; normalized, annealed or heat-treated; S. A. E. steels, Mayari nickel-chromium steels, Mayari engine bolt and staybolt steels, silico-manganese-spring steel; Supertemp, for superior physical properties at high temperatures; Nitralloy; bars, strip, billets and blooms.

AXLES, WROUGHT STEEL—For passenger and freight cars; engine, tender and trailer trucks; electric cars; mine locomotives and mine cars; cinder, ore and other industrial cars.

BANDS—Pipe and Tank Bands.

BARGES AND HULLS—Steel.

BARs, IRON—Chain, staybolt and engine bolt iron and muck bar.

BARs, STEEL—Black, as rolled; annealed, heat treated; cold drawn, turned or ground; S. A. E. specification and special analyses. Bessemer, open hearth and electric steels, alloy, special and carbon steels; merchant bars in regular and special shapes.

BARs, CONCRETE REINFORCING—New billet and rail steel; plain and deformed bars of constant section, in standard rounds and squares. Bent and spirals.

BINS, STEEL—Coal, coke, gravel, sand, etc.

BLANKS—Rolled steel gear blanks; fly wheels, crane wheels, tire molds and mold rings, shaft couplings, brake wheels, brake drums and other circular forgings.

BLAST FURNACE AND STEEL WORKS CONSTRUCTION.

BOILER TUBES—Genuine old-fashioned knobbled charcoal iron tubes, lap-welded. Double pass steel tubes, double pass copper-bearing steel tubes. Locomotive tubes.

BOLTS—All kinds; plain and galvanized; heat-treated, carbon and alloy steels; machine, cap, large and special types; Mayari steel frog, track and fitting-up bolts; staybolts, hollow and solid. Dardet self-locking threaded bolts. Bolt ends. Clevises. Turnbuckles. Sleeves.

BRIDGES, STEEL—Cantilever, Catenary, Girder, Lift, Signal, Suspension, Truss and other bridges. Steel Frame Trestles, Viaducts, Coal and Ore Handling Bridges and trestles.

BUILDINGS—Machine, Foundries, Power Houses, Mill and Industrial Buildings; Office, Hotel, Apartment Buildings; Railway Passenger and Freight Depots and Terminals. Train-sheds; Public Buildings; Grandstands; Freight, Recreation and Tubular Piers; Warehouses.

BUILDING MATERIALS, STEEL—Expanded and sheet metal lath; base and Corner beads; picture mold, channels, channel and lath clips, hanger rods; furring,

ALLOY STEELS

PARTIAL LIST OF PRODUCTS—Continued

furring extension rods, metal furring staples; building anchors, anchor slots and inserts; header angles; tie wire; joist bearing plates, bridging clips, bridging wire; wall ties; steel door frames; extruded-metal blackboard frames.

CAISSONS, BRIDGE.

CARS, MINE-AND-INDUSTRIAL—Built to any specifications.

CARS, STEEL FREIGHT—Ballast, flat, gondola, hopper, steel box, tank and dump cars.

CARS, STEEL PASSENGER—Passenger, baggage, express, mail, dining, private, special and combination cars.

CAR PARTS—Pressed steel parts; underframes; car truck and body bolsters; car castings; car forgings; coupling links and pins; brake and brake lever pins; car trucks.

CAR WHEELS, WROUGHT STEEL—Rolled steel wheels for freight cars, passenger cars, engine, tender and trailer trucks, electric cars, mine locomotives and mine cars, and cinder, ore and other industrial cars.

CASTINGS—Carbon and alloy steel (acid and basic open hearth and electric); manganese steel; iron; brass and bronze; rough as cast or machined. Centrifugal cast bronze sleeves and liners. Abrasion-resisting castings. Tunnel-segments, iron and steel.

CONCRETE REINFORCING MATERIALS—Round and square reinforcing bars; bar supports and spacers, slab bolsters, floor clips, spreader extensions; welded wire fabric; removable and permanent steel tiles, removable steel column forms; column spirals; concrete inserts.

DERRICKS, Miscellaneous.

DOCKS—Ore.

DREDGES, Steel.

DRYERS, Rotary- (Kilns).

FABRICATED STEEL CONSTRUCTION—All kinds.

FENCE, WOVEN WIRE—Bethanized woven wire field and poultry fence. Bethanized stiff-stay field and poultry fence. Bethanized Lawn Fence.

FERRO-MANGANESE.

FLANGED PRODUCTS—Tank heads, boiler heads, dome sheets, manheads, yokes, bolts and saddles. Miscellaneous flanged plate work.

FLUMES—Steel.

FORGINGS—Carbon and alloy steel; Drop, upset, hammered, and hydraulically pressed forgings; seamless vessels for boilers, high pressure seamless boiler drums and chemical vessels, Crankshafts, Rotors for turbines and generators.

TRACKWORK FOR RAILWAYS—Frogs, switches, chord, flange guardrails, crossings. Bethlehem and New Century switch standards. Silico-manganese special trackwork, portable trackwork. Switch heaters, standard rail chairs, compromise joints, steel ties, gage rods, rail braces.

GAS HOLDERS—Pressure, multiple lift.

GATES, STEEL—For farm, garden, lawn and poultry fencing.

BETHLEHEM STEEL COMPANY

PARTIAL LIST OF PRODUCTS—Continued

GEARS AND PINIONS—Cut and cast bevel; spur with straight or herring-bone cut teeth, any size; mill reduction gearing and pinions; gears for bridge operating machinery.

HIGHWAY BUILDING MATERIALS—STEEL—Bar mats, bolsters, supports, clips, spacers; welded wire fabric; road mesh; expansion or contraction joints, tubes, fillers, dowels, dowel bars; road strip; guard fencing; Kalguard (steel highway guard).

HULLS, Steel-Dredge, Boat and Barge.

HYDRAULIC MACHINERY.

INGOT MOLDS, STOOLS AND BOTTOM PLATES—All sizes.

JOISTS (Open-web steel)—“Mac Mar” and “Kalman.” Open-web expanded and welded steel joists.

KETTLES—Galvanizing.

KILNS—Cement, Rotary.

NAILS, WIRE—All kinds and sizes; standard and special; galvanized, cement-coated, annealed, blued and bright. Miscellaneous wire brads.

NUTS—Hot forged, hot pressed, and cold punched; semi-finished; bar, jam, slotted, chamfered and trimmed, blank, special lock-nuts; oil-quenched and Bethlehem treated. Dardelet self-locking threaded nuts.

OIL BURNING EQUIPMENT—Bethlehem (Dahl) mechanical atomizing oil burning systems for stationary and marine service.

OIL REFINERY EQUIPMENT.

PIG IRON—Basic, bessemer, semi-bessemer, foundry, low phosphorus, malleable, malleable bessemer, and Mayari pig iron for superior alloy-iron castings.

PILING, STEEL—Bethlehem steel sheet piling for bulkheads, jetties, cofferdams, and similar applications. Steel **H**-piling.

PIPE, STEEL—Butt-welded and lap-welded, black and galvanized; copper-bearing pipe; Welded and riveted pipe of large diameter.

PENSTOCKS—Steel.

PLATES, STEEL—Universal and sheared plates for all purposes. Steel plate work. Floor plates. Slabs.

POLE LINE MATERIAL—Black and galvanized.

PONTOONS, STEEL.

POSTS, STEEL FENCE—Farm, garden, lawn and poultry fence posts, snow fence posts, highway sign posts.

RAILS AND ACCESSORIES—Standard tee rails; girder, girder-guard and high tee rails; light rails; splice bars, rail clips, tie plates, Bethco rail anchors.

RIVETS, STEEL AND IRON—Small and large; Boiler, structural, ship, bridge, tank and tap.

RODS—Bridge, Truss, Loop and Roof; Round and Flat Tie; Silo; Upset; Wire; Guy.

ROLLS—Steel and Iron.

SAND, WASHED LIMESTONE.

ALLOY STEELS

PARTIAL LIST OF PRODUCTS—Continued

SCREWS—CAP AND SET—Square, button, flat fillister, oval fillister and hexagon heads.

SEMI-FINISHED STEEL—Ingots, blooms, billets and slabs. Bessemer, open hearth, electric furnace, carbon steels. Re-rolling and forging quality; Sheet bars. Skelp, grooved, universal and sheared.

SHAFTING, STEEL—Cold drawn; forged solid or hollow; turned and polished.

SHEETS, STEEL—Hot rolled, hot-rolled annealed, cold-rolled, heavy cold-rolled sheets, deoxidized; furniture, heavy furniture, elbow, stove pipe, japanning, porcelain enameling sheets; automobile sheets; tack plate; galvanized flat and formed sheets; painted formed sheets; special-finish sheets; sheets of Beth-Cu-Loy (copper-bearing steel). Culvert stock. Ridge roll. Stormproof Roofing and Siding.

SMOKE STACKS, STEEL—Guyed and self-supporting.

SPIKES—Standard railroad, screw track, universal screw, tie-plate screw, boat, dock and wharf spikes. Round and gutter or eavestrough wire spikes.

STANDPIPES, STEEL.

STAINLESS STEELS—Bethadur and Bethalon, covering practically every need for heat-resisting and corrosion-resisting steels, including free-machining grades.

STAPLES—Fence, fence post, ribbon wire, poultry netting, galvanized hoop, and metal lath.

STEELWORKS CONSTRUCTION—Blast furnaces, steel converters, bins, furnace ladles, hot metal mixers, gas purifiers and scrubbers, hot blast stoves, tanks, charging boxes, ore handling bridges, mill buildings, ore docks and steel plate work.

STILLS, STEEL—Oil, Tar, Riveted.

STRIP—Bessemer, open hearth and electric steel; Alloy and special steel, Hot-rolled new billet steel, hot-rolled rail steel; Cold-rolled strip. Black as rolled, annealed, heat-treated. Coils and flat.

STRUCTURAL STEEL SHAPES—Bethlehem wide-flange beams, girders and H-columns, joists and stanchions; standard beams, channels, and angles; car and shipbuilding shapes; standard and special T-and Z-bars.

SUCKER RODS—Mayari; nickel-chromium; copper-bearing sucker rods; pony rods, pull rods.

TANKS, STEEL PLATE—All kinds.

TIN PLATE—Hot pack and cold reduced; coke tin plate; canners special; galvanizing; black plates (hot rolled annealed, deoxidized, cold reduced, pickled annealed, pickled annealed cold rolled annealed [full finish], enameling and lithographing stock). Terne plate, special coated.

TOOL STEELS—Bethlehem special high speed steel. Carbon and alloy tool steels. Air hardening, water hardening, oil hardening, cold cutting and die, hot die, shock resisting, non-deforming, quarrying, cobalt magnet, valve and special tool steels. Tool steel billets, all grades.

TOOLS—Rivet sets, punches and dies, chisel blanks and chisels; hot and cold friction saws; steel stamps (letters and figures for hot and cold work). Slitting shears, shear blades, and special high speed tool holder bits, special tools.

PARTIAL LIST OF PRODUCTS—Concluded

TIPPLES, STEEL—Coal and Mine Tipples and Head frames.

TOWERS AND POLES—Structural steel; Transmission Line; Flood-light; Airway Beacon; Radio, etc.

TUBES AND TUBING, STEEL—Boiler, Locomotive Boiler, Oil Country, Superheater, Gas and well; welded.

TURNTABLES—RAILROAD—Bethlehem Twin-span Turntables. Balanced and Continuous Turntables.

WASHERS—Iron and Steel—Round plate.

WIRE—Made from Bessemer, Basic Open Hearth or Acid Open Hearth grades of Steel: In various finishes such as plain; bright-processed; annealed; normalized; galvanized; Bethanized (special zinc-coated); soft-processed; lime-bright annealed; annealed, cleaned and lime coated; annealed, cleaned and oiled; and high carbon patented. Bolt, screw, chain, extra-soft rivet, hard bright nail wire; stapling wire, border wire, Apex and Bethlehem spring wire, telephone wire, heading wire, Copper-bearing and Special wire. Clothes-line wire. Barbed wire, Silver Star Bale ties. Welding Wire.

WIRE RODS—Basic, bessemer and acid open hearth.

WIRE SPECIALTIES—Fasteners, Handles, Hangers, Hooks, Hoops, Links, Loops, Picket or Tent Pins, Rings, Skewers, Double-pointed Tacks.

WOOL, INSULATING—Granulated and in bats.

BETHLEHEM STEEL COMPANY

General Offices

BETHLEHEM, PENNSYLVANIA

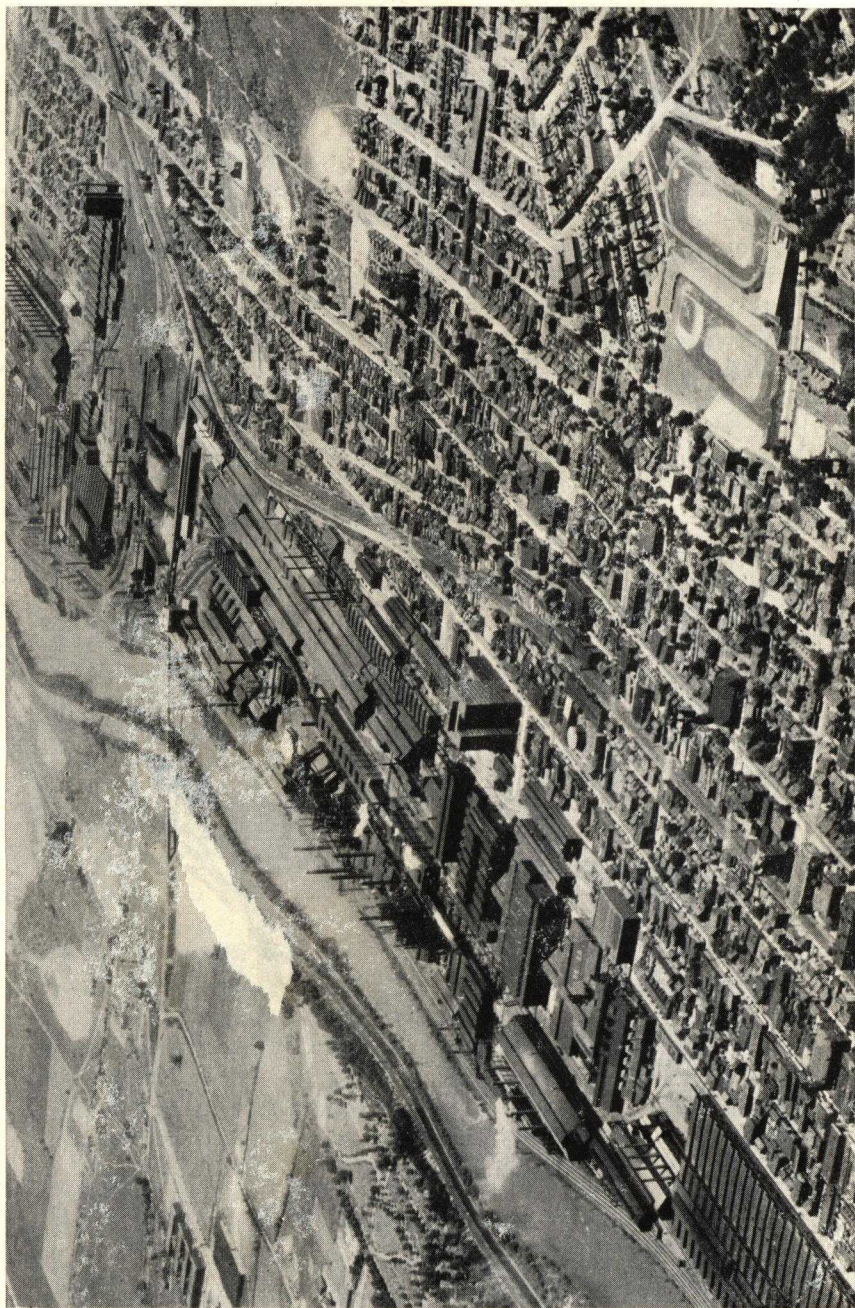
District Offices

Albany	Standard Building
Atlanta	Candler Building
Boston	75 Federal Street
Baltimore	Mercantile Trust Building
Bridgeport, Conn.	Security Building
Buffalo	Hamburg Turnpike, Lackawanna, N. Y.
Chicago	Wrigley Building
Cincinnati	Union Trust Building
Cleveland	Terminal Tower
Dallas, Tex.	Magnolia Building
Detroit	General Motors Building
Hartford, Conn.	125 Trumbull Street
Honolulu	Schuman Building
Houston	Petroleum Building
Indianapolis	Circle Tower
Kansas City, Mo.	1302 Commerce Building
Los Angeles	Downey Road and E. Slausen Ave.
Milwaukee	Warner Theatre Building
New York	25 Broadway
Philadelphia	Broad Street Station Building
Pittsburgh	Oliver Building
Portland, Ore.	American Bank Building
Salt Lake City	924 Kearns Building
San Antonio	Smith-Young Tower Building
San Francisco	20th and Illinois Streets
St. Louis	Telephone Building
St. Paul	First National Bank Building
Seattle	28th Avenue S. W. and W. Andover Street
Syracuse	Union Building
Washington, D. C.	American Security Building
Wilkes-Barre	Miners National Bank Building
York	Small Building

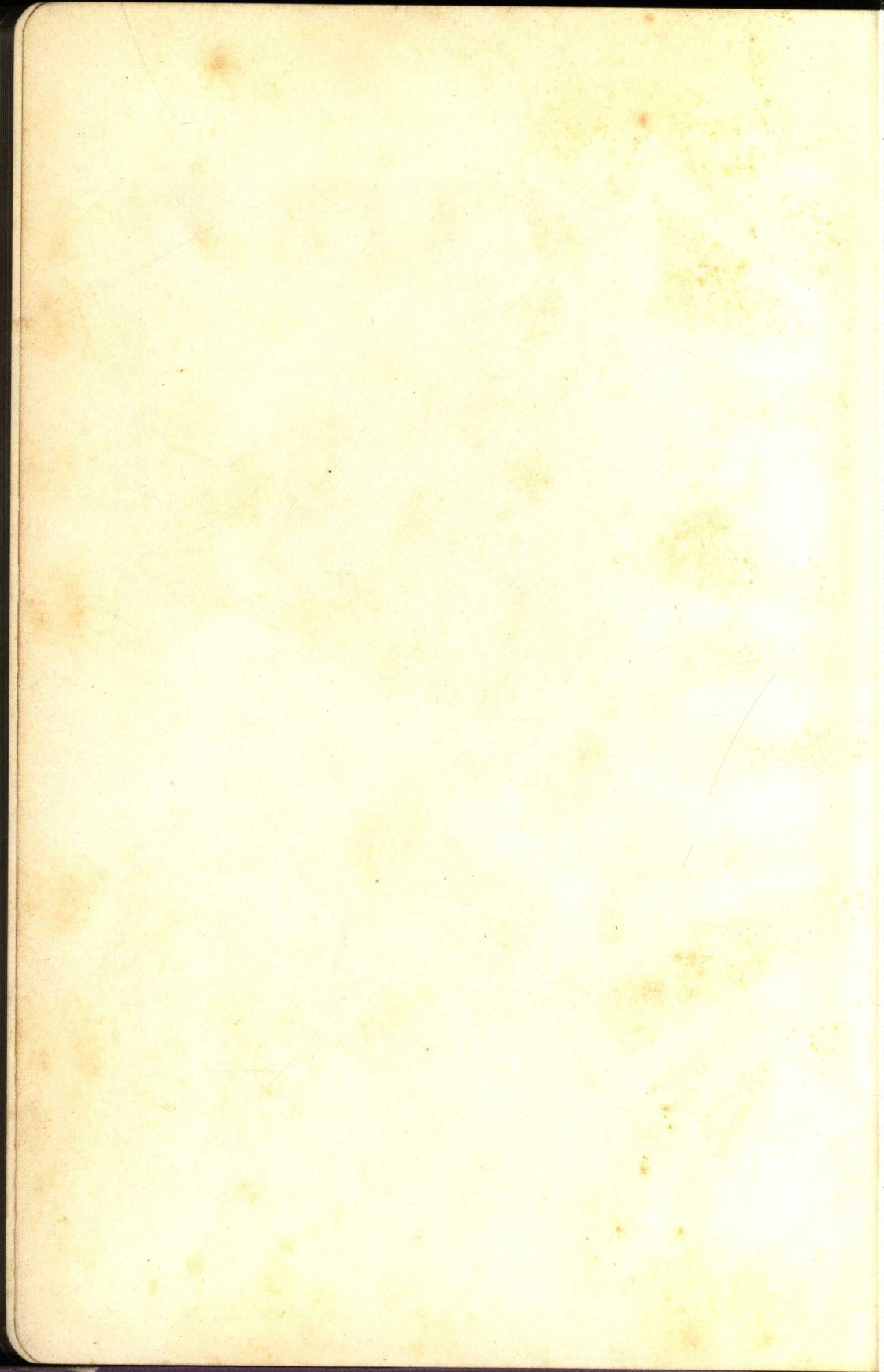
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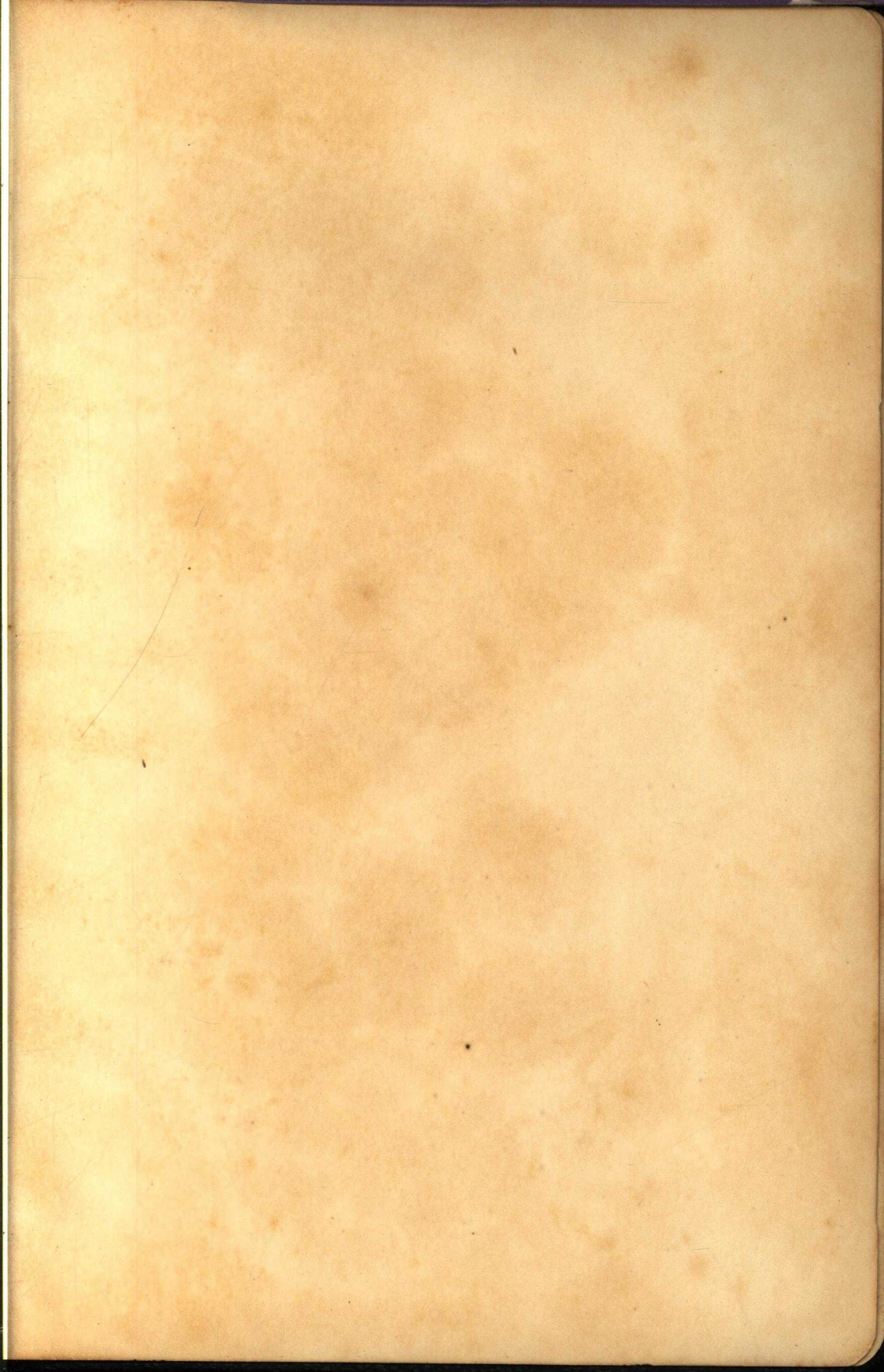
BETHLEHEM STEEL EXPORT CORPORATION
25 Broadway, New York City

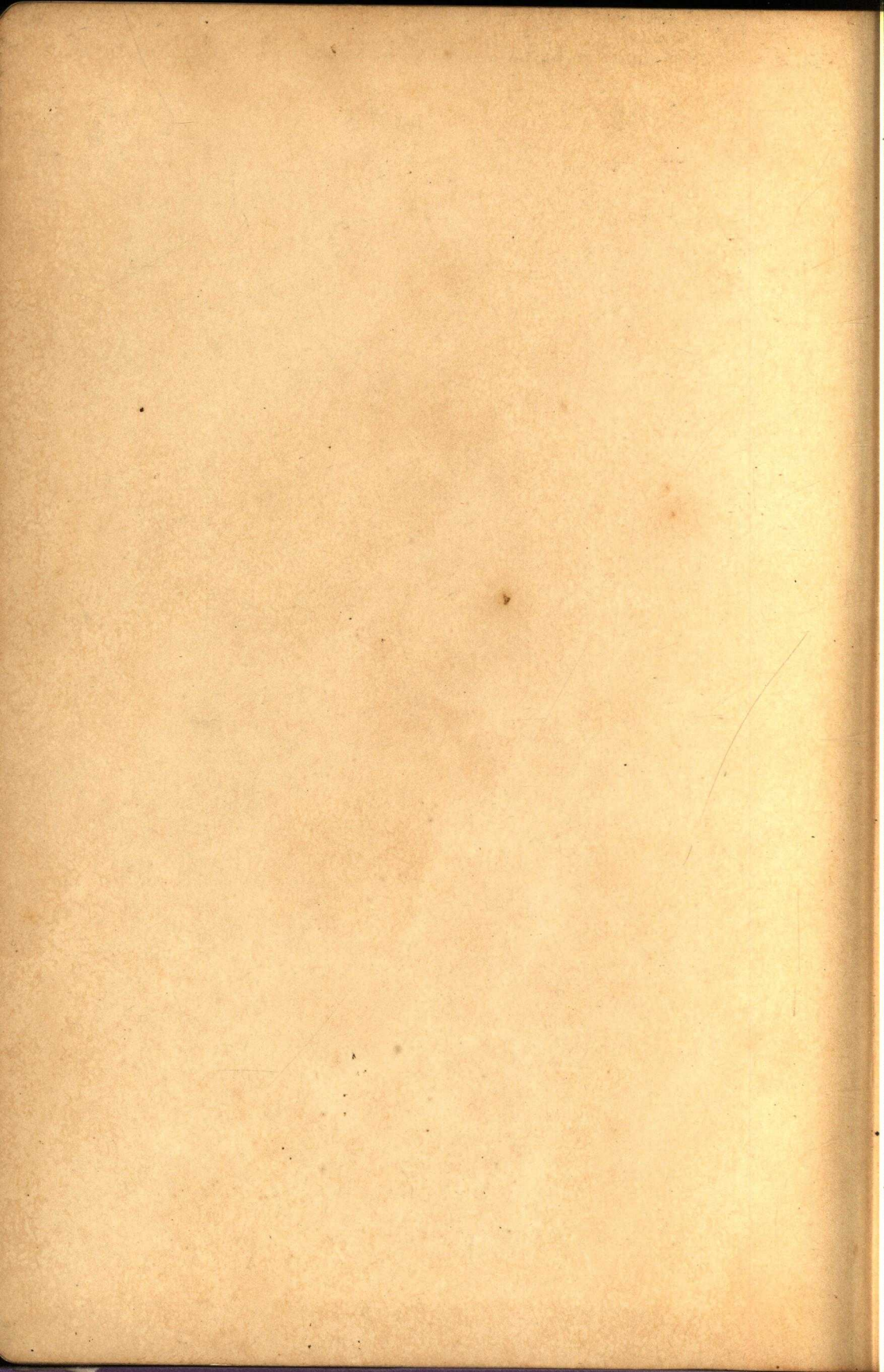
BETHLEHEM STEEL COMPANY

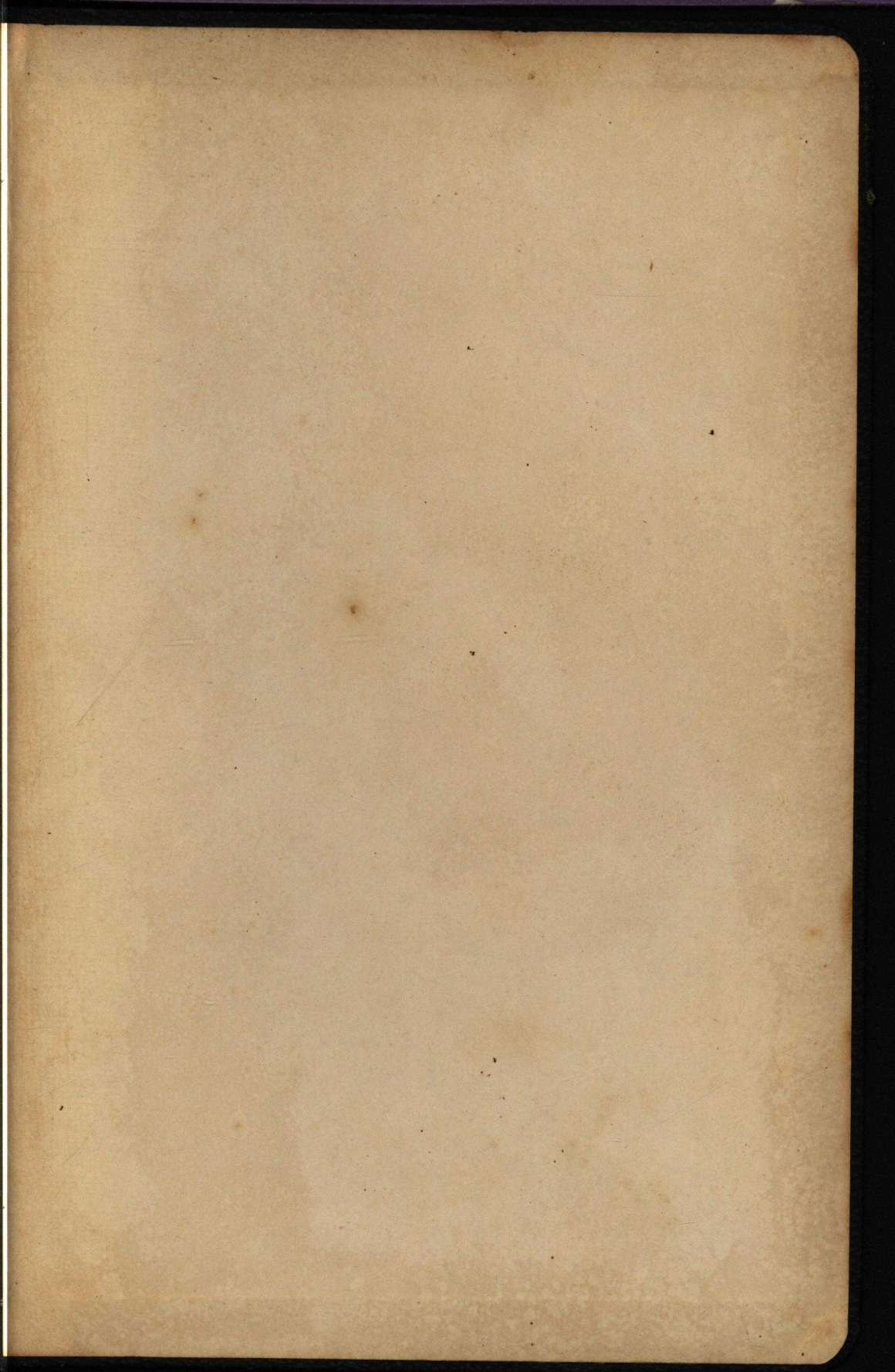


Airplane view of part of Lehigh plant, Bethlehem Steel Company, Bethlehem, Pa.









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